INDUSTRIAL ABATEMENT- AIR MANAGEMENT

PART 1

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Ministry
of the
Environment

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MINISTRY OF THE ENVIRONMENT
INDUSTRIAL ABATEMENT
AIR MANAGEMENT

PART I

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INTRODUCTION

The *Industrial Abatement Air Management* manual has been prepared to assist the trainee and the instructor to achieve the objectives of the *Industrial Abatement-Air Management Course*, which has been developed to familiarize new personnel with the air management aspects of Industrial Abatement, and to increase the efficiency of provincial officers involved with those duties.

The course consists of three parts, each of approximately five days duration. In order to qualify for the award of a certificate, the trainee must have achieved a pass mark of at least 70 per cent in the examination set at the end of each part of the course.

This certification course is one of a series of courses, seminars and workshops regularly offered by the Ontario Ministry of the Environment, Training and Certification Section in Toronto.

    Part I   covers Topics 1 to 10
    Part II   covers Topics 11 to 16
    Part III covers Topics 17 to 23

ACKNOWLEDGEMENTS

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Part I

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SUBJECT:

INDUSTRIAL ABATEMENT -
AIR MANAGEMENT

TOPIC: 1

Air Contaminating Processes
and Contaminants

OBJECTIVES:

The trainee will be able to:

1. List the three forms of air conta-
   minating processes, combustion,
   vaporization and mechanical attrition
   and briefly explain what is meant
   by these terms;

2. Define or explain the following:
   Smoke, fume, vapour, mist, gas,
   calcination, sublimation, distil-
   lation, organic gas, inorganic gas;

3. Explain why nitrogen oxides, sulphur
   oxides and carbon monoxide are
   undesirable constituents of the
   atmosphere.

SOURCES OF AIR POLLUTION

General

Ever since man has attempted to satisfy his basic needs by seeking ways to manipulate his environment more efficiently, one form or another of air pollution has been present to plague him. The various periods of human history, the ages of fire, copper, bronze, iron and atomic, testify to the fact that man has always engaged in air polluting activities.

In 1257 AD, the smoke of Nottingham was so bad that Queen Eleanor, the wife of Henry the Third, was compelled to move to Tutbury. In 1306 AD, a royal proclamation prohibited the use of coal in certain furnaces, with a Commission appointed to punish offenders. The first offence being fines, second, demolition of the furnaces, and the third offence execution, and history records one such execution.

One of the first recommendations to control smoke was by Thomas Owen, who in 1595 AD proposed to transport smokeless coal from South Wales to London.

In 1661 AD coal smoke was so bad that the diarist, John Evelyn, in writing about London stated "the weary Traveller at many Miles distance, sooner smells, than sees the City".

Initially these air polluting activities were isolated in small settlements and towns and were treated as individual cases of smokes and fumes, affecting only those living close to the sources of air pollution, but with the impact of the industrial revolution in the eighteenth and nineteenth centuries,

cities grew and air pollution nuisances increased in frequency and complexity, giving rise to total pollution of entire metropolitan air spaces.

Thereafter, in England the smoke problem was attacked on a community basis, the first anti-smoke ordinance being adopted in 1847. In the U.S.A., the first was in Chicago in 1881, and in Toronto, 1907.

It was not until the twentieth century that the resources of science and technology began to be applied to the control of municipal air pollution with any degree of concentration, when considerable knowledge of the nature and control of air pollution emerged. Even so, in the early part of the century, control programmes were designed to control visible emissions, with the emphasis on smoke.

It is only perhaps in the last twenty years that air pollution control legislators have become far-sighted enough to tackle effectively the more sophisticated problem of air pollution; the pollution which often cannot be seen. In this period the problem of air pollution has been subject to many professional disciplines, including engineering, law, public administration, economics, medicine and most of the major fields of pure and applied science.

To the extent that there is a constant and varied activity taking place on the surface of the earth, the general concept of air pollution includes a large variety of specific air pollution problems. These can be divided into two broad classes, Natural and Man-Made.

Natural Pollution

Natural sources of air pollutants include:

wind blown dust
volcanic ash and gases
ozone from lightning and the ozone layer
esters and terpenes from vegetation
smoke, gases and fly ash from forest fires
pollens and other aeroallergens
gases and odours from natural decomposition
natural radioactivity

Such sources constitute background pollution and that portion of the pollution problem over which control activities can have little, if any, effect.

Man-Made Pollution

Such pollution is a by-product of a civilization which has become dependant on its technology in industry for its survival. Modern civilization has progressed by the replacement, substitution or extension of manual or natural activities, such as those found in primitive economies, with mechanical devices and synthetic or fabricated materials. These involve industrial techniques, vehicular, marine and aerial forms of transportation, mass communication, rapid distribution of raw materials and manufactured products, centralization of energy and heat sources, together with all services necessary to the construction and maintenance of an urban community. Five main classes of pollutants, particulates, carbon monoxide, hydrocarbons, nitrogen oxides and sulphur oxides, are summarized nationally for the year 1978 in Table 1-1. Table 1-2 is a detailed breakdown of the five contaminants on a source by source basis.
(In draft status Nov. 1982)

TABLE I   NATIONWIDE EMISSIONS OF AIR CONTAMINANTS, 1978

Category	Emissions (tonnes x 10^3)									
	Particulate matter	% of total	Sulphur oxides*	% of total	Nitrogen oxides**	% of total	Hydro-carbons	% of total	Carbon monoxide	% of total
Industrial processes	1 439	59.1	2 770	62.2	50	2.7	47	26.9	1 070	11.0
Fuel combustion/ stationary sources	275	11.3	1 537	34.5	652	35.3	116	5.8	308	3.1
Transportation	92	3.8	143	3.2	1 115	60.5	851	42.7	7 245	74.3
Solid waste incineration	36	1.5	3	0.1	5	0.3	31	1.6	376	3.9
Miscellaneous	592	24.3	-	-	22	1.2	577	29.0	755	7.7
TOTAL	2 434	100.0	4 473 (4 453)	100.0	1 849 (1 844)	100.0	1 992	100.0	9 754	100.0

*   Expressed as SO_2
**   Expressed as NO_2

Source: ENVIRONMENT CANADA ECONOMIC AND TECHNICAL   REVISED
REPORT EPS 3-AP-82-1

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TABLE -2 NATIONWIDE EMISSIONS OF AIR CONTAMINANTS, BY SOURCE, 1978

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
INDUSTRIAL PROCESSES					
Iron ore mining and beneficiation	280 619	151 550	-	-	38 104
Pyrrhotite roasting	2 369	26 171	-	-	-
Iron and steel production	71 066	2 423	-	-	252 595
Primary aluminum production	58 320	52 086	8 403	1 448	146 690
Primary copper and nickel production	45 500	1 639 453	-	-	-
Copper and nickel refining	2 046	833	-	-	-
Primary lead and zinc production	12 252	113 187	-	-	-
Ferroalloy manufacture	25 367	1 783	-	-	15 754
Abrasives manufacture	7 530	7 874	-	-	6 723
Ferrous foundries	12 062	-	-	-	6 715
Magnesium production	330	-	-	-	-
Asbestos production	76 825	-	-	-	-
Mining and rock quarrying	192 809	-	-	-	-
Salt production	10 143	-	-	-	-
Lime manufacturing	28 803	-	-	-	-
Gypsum processing	19 537	-	-	-	-
Nepheline syenite processing	458	-	-	-	-
Potash processing	22 800	-	-	-	-
Silica processing	1 068	-	-	-	-
Stone processing	36 203	-	-	-	-
Sand and gravel processing	13 299	-	-	-	-
Cement manufacture	47 533	-	-	-	-
Concrete batching	2 209	-	-	-	-
Asphalt production	64 259	-	-	-	-
Glass manufacturing	1 410	-	-	-	-

Source: ENVIRONMENT CANADA ECONOMIC AND TECHNICAL
          REVISED REPORT EPS 3-AP- 82-1

TABLE -2 NATIONWIDE EMISSIONS OF AIR CONTAMINANTS, BY SOURCE, 1978,
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
Clay products manufacture	12 721	-	-	-	-
Crude oil production	-	-	-	29 454	-
Petroleum refining	12 201	89 148	4 273	163 937	421 274
Natural gas processing	-	434 891	-	2 348	-
Tar sands operations	9 606	107 602	13 653	9	210
Coal industry	79 466	-	-	-	-
Metallurgical coke manufacture	19 951	7 759	23	1 627	1 541
Petrochemical Industry	-	-	-	181 119	-
Plastics Fabrication	-	-	-	19 763	-
Carbon black	18	2 491	-	111	161 061
Sulphuric acid production	-	20 415	-	-	-
Nitric acid production	-	-	6 944	-	-
Phosphoric acid production	71	-	-	-	-
Phosphate rock processing	4 628	-	-	-	-
Phosphate fertilizer manufacture	4 349	-	-	-	-
Elemental phosphorus production	10 675	2 115	-	-	-
Nitrate fertilizer manufacture	6 578	-	170	-	-
Grain handling and milling	65 046	-	-	-	-
Bakeries	-	-	-	3 749	-
Sulphate (kraft) pulping	106 500	35 371	16 589	12 823	19 595
Sulphite pulping	1 442	74 924	-	-	-
Sawmills	61 000	-	-	-	-
Pulpboard manufacture	1 770	-	-	142	-
Plywood and Veneer	8 327	-	-	294	-
Subtotal	1 439 166	2 770 076	50 055	416 825	1 070 262

TABLE -2 NATIONWIDE EMISSIONS OF AIR CONTAMINANTS, BY SOURCE, 1978,
(continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
FUEL COMBUSTION/STATIONARY SOURCES					
Power generation by utilities	*157 866* ~~157 222~~	*729440* ~~705 141~~	*236449* ~~230 845~~	4 850	17 290
Residential fuel combustion	8 739	102 489	45 906	4 763	19 667
Industrial fuel combustion	60 786	620 848	320 330	47 433	34 628
Commercial fuel combustion	9 477	108 641	49 108	1 887	6 528
Fuelwood combustion	38 334	-	5 749	57 500	230 002
Subtotal	*275 202* ~~274 558~~	*1561418* ~~1 537 119~~	*657542* ~~651 938~~	116 433	308 115
TRANSPORTATION					
Gasoline-powered motor vehicles	42 806	18 778	474 090	677 042	5 850 521
Railroads	6 903	32 468	101 433	25 357	36 886
Marine	4 666	48 087	26 334	29 780	71 400
Aircraft	1 430	2 287	38 006	9 089	87 285
Off-road use of gasoline	1 959	1 473	31 528	55 870	1 051 358
Diesel-powered engines	31 084	40 177	443 236	53 083	147 328
Tire wear	3 341	-	-	668	-
Subtotal	92 189	143 270	1 114 627	850 889	7 244 778
SOLID WASTE INCINERATION					
Municipal incineration	4 976	1 367	1 543	774	18 500
Industrial and commercial incineration	1 112	666	727	223	801
Sewage sludge incineration	133	586	184	47	Neg.
Wigwam burners	30 180	275	2 744	30 180	356 695
Subtotal	36 401	2 894	5 198	31 224	375 996

TABLE -2   NATIONWIDE EMISSIONS OF AIR CONTAMINANTS, BY SOURCE, 1978, (continued)

Source	Emissions (tonnes)				
	Particulate matter	Sulphur oxides*	Nitrogen oxides**	Hydro-carbons	Carbon monoxide
MISCELLANEOUS					
Fertilizer application	6 910	-	-	-	-
Pesticide manufacturing and application	26 716	-	-	-	-
Gasoline and diesel marketing	-	-	-	234 451	-
Dry cleaning	-	-	-	25 476	-
Application of surface coatings	-	-	-	128 430	-
Structural fires	6 778	-	-	6 778	13 552
Cigarette smoking	4 313	-	-	-	1 726
General Solvents Use	-	-	-	72 427	-
Landfill Sites	-	-	-	15 437	-
Forest Fires	463 508	-	12 362	74 160	494 410
Slash Burning	83 550	-	9 831	19 659	245 739
Subtotal	591 775	-	22 193	576 818	755 427
TOTAL	~~2 434 089~~ 2434 733	~~4 453 359~~ 4477 658	~~1 844 011~~ 1849 615	1 992 188	9 754 578

* Expressed as SO_2
** Expressed as NO_2

These activities can be reduced to three forms of air contaminating processes:

1. Combustion
2. Vaporization
3. Mechanical attrition

COMBUSTION

The combustion of fossil fuels and waste materials for heat, steam and electrical energy is applied universally to provide warmth, metal melting, motive power, food processing, incineration of waste materials, baking, tempering, curing and many other processes. The products of combustion, smoke and gases, comprise contaminant plumes typical of all cities.

Smoke

Smoke is the visible effluent resulting from incomplete combustion. It consists mostly of soot, fly-ash and other solid or liquid particles less than one micrometre in diameter. Depending upon the composition of the fuel or materials being burned and the efficiency of combustion, various volatilized gases and organics such as aldehydes, various acids, sulphur oxides, nitrogen oxides and ammonia may also be emitted. Due to the low vapour pressure and slow settling properties of the particles, the smoke may be carried considerable distances from the source and many submicrometre particles will be permanently dispersed in the atmosphere.

Smoke will vary in colour, but will be generally observed as grey, blue, black, brown and white, and sometimes yellow, depending upon the conditions under which certain types of fuels or materials are burned. The colour of smoke is generally a fairly

good indication of the type of combustion problem
encountered.

Smoke which is grey or black in colour may
indicate that material is being burned with insufficient
air or inadequate mixing of fuel and air.

White smoke usually results when combustion
is cooled by excess drafts of air, or when the materials
being burned contain excessive amounts of moisture.

Brown or yellow smoke may result from the
burning of semi-solid tarry substances such as asphalt
or tar paper, resulting from inadequate temperature
and mixing.

A blue colour or light blue colour is often
associated with the burning of domestic trash consisting
mostly of paper or wood products. The light blue
colour seems to stem from the fine particles of pyro-
ligneous acid due to sulphide treated paper and wood
tar constituents. The blue plume contains little or
no carbon or soot particles.

VAPORIZATION

Vaporization, or volatilization, is a by-
product of a large variety of chemical and manufacturing
processes which induce physical changes in substances
through the application of heat and pressure, thereby
causing some component materials to vaporize in the
atmosphere. Vaporization includes the evaporation of
volatile materials at normal atmospheric temperatures
and pressures; fuming as a result of induced tempera-
tures; and decomposition of organic materials as a
result of natural processes. Some materials with high

vapour pressures will evaporate within the range of
normal atmospheric temperature and pressure conditions.
These include petroleum derivatives, such as gasoline
and fuel oil, which are consumed by the entire economy,
from motor vehicles and fuel oil burning to organic
solvent usage.

Fumes

In air pollution control, fumes are referred
to specifically as "condensed fumes". These are minute
solid particles generated by the condensation of vapours
from solid matter after volatilization from the molten
state, or may be generated by sublimation, calcination
or chemical reaction when these processes create air-
borne particles. Fume particles are generally less
than one micrometre in diameter and will behave like
smoke. Fumes will more commonly consist of metals
and metallic oxides and chlorides. Also contained in
the fumes are common solid particulates such as fly—
ash, carbon, mechanically-produced dust and gases such
as sulphur dioxide. The fumes principally emitted,
however, are actually dusts condensed from the more
volatile elements in the metals melted such as zinc,
sulphur, lead and others.

The provincial officer will probably be
mostly concerned with metallurgical fumes. The metal-
lurgical fume will consist primarily of the metallic
oxide which is driven from the melting surface when
metal is heated to the molten state. Metals such as
copper and bronze with relatively high boiling tempe-
ratures, as compared to their melting and pouring
temperatures, do not readily volatize and do not con-
stitute an air pollution problem. Copper and tin, for

example, have boiling temperatures above 2 200°C, but are poured at temperatures at about 1 090°C.

Some metals may contain alloys with extreme differences in volatility. Copper-based alloys such as yellow brass, manganese bronze, brazing spelter and various plumbing metals contain from 15 to 40 per cent zinc, the boiling temperature of which is around 1 200°C. Since the metal must be heated to melt the copper which has the highest pouring temperature, a portion of the zinc will be brought to its boiling point and will volatilize. Copper alloys with high zinc contents may lose from 2 to 15 per cent of their zinc through fuming.

When vented to the atmosphere, fumes may have the appearance of smoke. However, all of the sources of fumes may not be practically vented in a large-scale foundry operation, so that fumes in the vicinity of a plant may appear as a haze or a cloud emitted from factory monitors or windows.

Other processes which will produce fumes include calcination, sublimation and distillation.

Calcination consists of heating, roasting or smelting to decompose minerals. Calcination is commercially applied in the manufacture of glass and mineral catalysts through the heating of materials such as sand and limestone. It is variously employed to remove moisture or a volatile constituent by such methods as heating limestone to form carbon dioxide gas and calcium oxide, or to reduce minerals by oxidation.

Sublimation is the process in which a solid substance is converted to a gas without a change in

composition and without first going through the
liquid state. Iodine, carbon dioxide (dry ice) and
many metallic and nonmetallic crystals are examples
of sublimed materials. Sublimation of these materials
may be accomplished by lowering the pressure, raising
the temperature or by changing both temperature and
pressure.

Distillation is a cycle of vaporization and
condensation in which a liquid is converted to a vapour
and condensed to a liquid. Distillation is generally
employed to purify a liquid or to segregate components
according to relative volatility.

Vapours

A vapour is the gaseous phase of a substance
which at normal temperature and pressure is a liquid
or solid.

The most important vapour air pollution
problem is that which results from the evaporation
of petroleum products, such as the unburned gasoline
vapours in automobile exhaust. Gasoline vapours also
originate from processes in which volatile products
are maintained in storage tanks and from the operation
of pumps, compressors and blowers required for moving
liquid gas streams.

Another principal source of vapours originates
from the consumption, marketing and manufacture of
paints and other coating products containing organic
solvents which are used to dilute or extend surface
coatings. These are released to the atmosphere upon
application.

MECHANICAL ATTRITION

These processes consist of crushing, grinding, drilling, demolishing, mixing, batching, blending, sweeping, sanding, cutting, pulverizing, spraying, atomizing of material, etc., which either directly or indirectly disperse particulates such as dusts and mists into the atmosphere.

Dusts

Dusts are produced from virtually every human activity as well as from the natural environment. Some dusty industries include mineral earth processors such as ceramic and cement manufacturing, calcining, and wood-working and feed and flour industries.

Dust particles mainly exceed one micrometre in diameter and are readily controlled by centrifugal separators, cloth filters and electrostatic precipitators.

Mists

Mists consist of liquid particulates or droplets, less than the size of raindrops, such as fog, and are formed by condensation of a vapour or atomization of a liquid by mechanical spraying. Mist droplets may contain contaminant material in solution or suspension. The impregnation and coating of building materials with asphalt or the manufacture or heating of asphalt at batch plants may produce hazes or fogs containing drops of liquid asphalt. Paint spraying operations emit liquid particulates containing organic solvents, pigments and other materials. Mists may

also be emitted from control devices such as cyclones
and scrubbers, using a liquid air cleaning medium.
Acid particulates, such as chromic and sulphuric acid
produced from chrome plating operations, may form
mists when exhausted to the atmosphere.

CONTAMINANTS

Air pollution is usually the unintentional
result of the conduct of some activity which emits
undesirable substances into the air in either one, or a
combination, of the following states:

1. Aerosols and particulates
2. Organic gases
3. Inorganic gases

Aerosols and Particulates

A particle is any dispersed matter, solid
or liquid, in which the individual aggregates are larger
than single molecules, but smaller than about 500 μm
in diameter. A continuous spectrum of sizes occurs
among the particles in the atmosphere, with corresponding
gradations in physical and chemical properties. Figure
1-1 illustrates the size range and some common charac-
teristics.

Variations in size confer different physical
and chemical properties on the particles. It is impor-
tant, therefore, to be familiar with the scale and
size ranges of common particulate substances and corres-
ponding changes in properties. For example:

FIGURE 1-1

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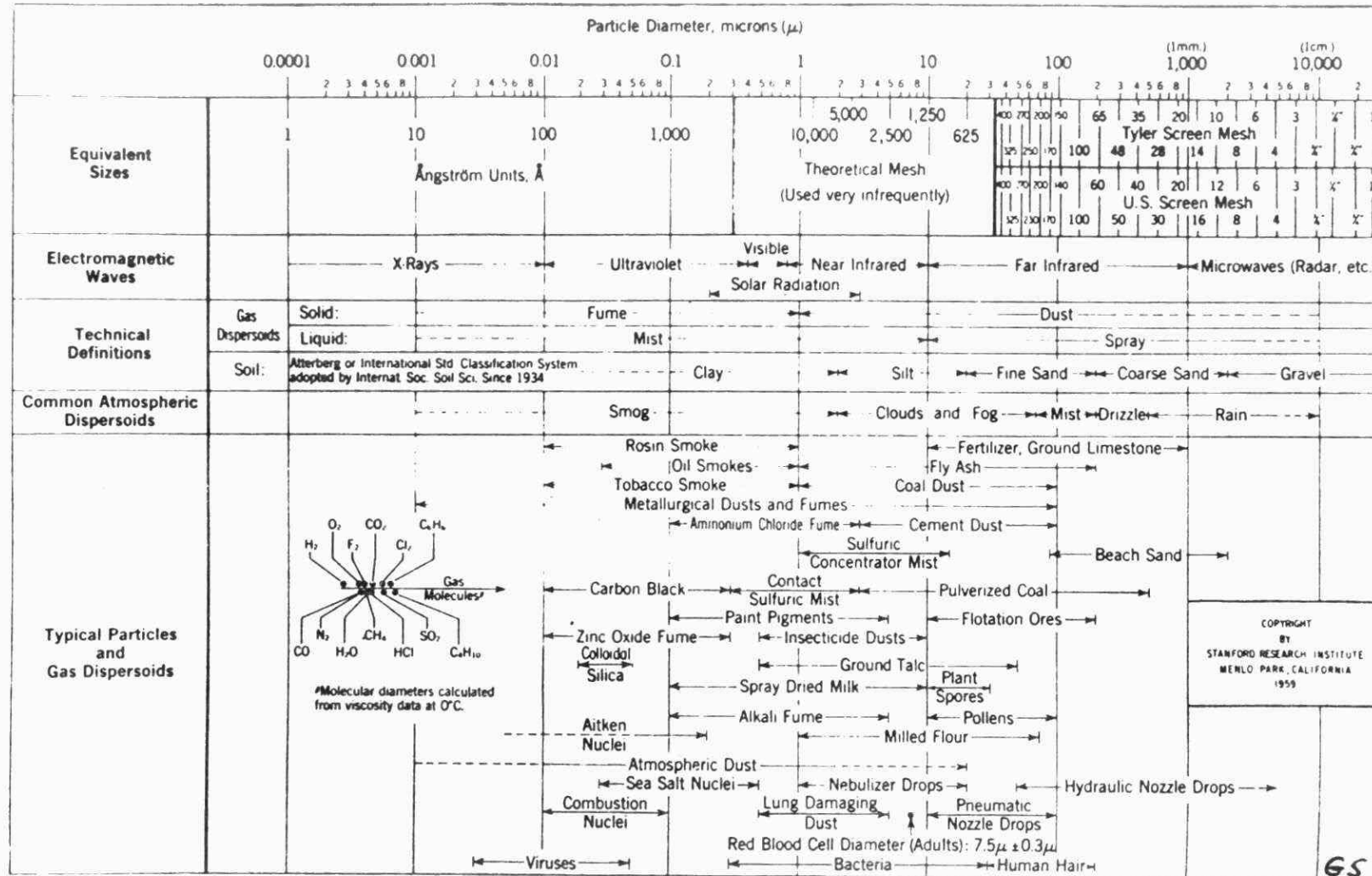# CHARACTERISTICS OF PARTICLES AND PARTICLE DISPERSOIDS

Particle Diameter, microns (μ)

0.0001	0.001	0.01	0.1	1	10	100	(1mm.) 1,000	(1cm.) 10,000

Equivalent Sizes

5,000 | 1,250

1 | 10 | 100 | 1,000 | 10,000 | 2,500 | 625

Tyler Screen Mesh

Ångström Units, Å

Theoretical Mesh (Used very infrequently)

U.S. Screen Mesh

Electromagnetic Waves

X-Rays — Ultraviolet — Near Infrared — Far Infrared — Microwaves (Radar, etc.)

Visible

Solar Radiation

Technical Definitions

Gas Dispersoids — Solid: Fume — Dust

Liquid: Mist — Spray

Soil: Atterberg or International Std Classification System adopted by Internat. Soc. Soil Sci. Since 1934 — Clay — Silt — Fine Sand — Coarse Sand — Gravel

Common Atmospheric Dispersoids

Smog — Clouds and Fog — Mist — Drizzle — Rain

Typical Particles and Gas Dispersoids

Rosin Smoke

Oil Smokes

Fertilizer, Ground Limestone

Fly Ash

Tobacco Smoke

Coal Dust

Metallurgical Dusts and Fumes

Ammonium Chloride Fume — Cement Dust

Sulfuric Concentrator Mist

Beach Sand

O_2 CO_2 C_4H_6

H_2 F_2 Cl_2

Gas Molecules

Carbon Black

Contact Sulfuric Mist

Pulverized Coal

N_2 CH_4 SO_2

CO H_2O HCl C_4H_{10}

Paint Pigments

Flotation Ores

Zinc Oxide Fume

Insecticide Dusts

Colloidal Silica

Ground Talc

Plant Spores

*Molecular diameters calculated from viscosity data at 0°C.

Spray Dried Milk

Alkali Fume

Pollens

Aitken Nuclei

Milled Flour

Atmospheric Dust

Sea Salt Nuclei

Nebulizer Drops

Hydraulic Nozzle Drops

Combustion Nuclei

Lung Damaging Dust

Pneumatic Nozzle Drops

Red Blood Cell Diameter (Adults): 7.5μ ±0.3μ

Viruses

Bacteria

Human Hair

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CHARACTERISTICS OF PARTICLES AND PARTICLE DISPERSOIDS

(continued)

FIGURE 1-1

1-17

Methods for Particle Size Analysis

— Impingers —
Electroformed Sieves
— Sieving —
— Ultramicrosocope[+] —
— Microscope —
— Electron Microscope —
— Centrifuge — — Elutriation —
— Ultracentrifuge — — Sedimentation —
— Turbidimetry[++] —
— X-Ray Diffraction[+] — — Permeability[+] —
— Visible to Eye —
— Adsorption[+] — — Scanners —
— Light Scattering[++] —
— Machine Tools (Micrometers, Calipers, etc.) —
— Nuclei Counter — — Electrical Conductivity —

[+] Furnishes average particle diameter but no size distribution.
[++] Size distribution may be obtained by special calibration

Types of Gas Cleaning Equipment

Ultrasonics (very limited industrial application)
— Settling Chambers —
— Centrifugal Separators —
— Liquid Scubbers —
— Cloth Collectors —
— Packed Beds —
— Common Air Filters —
— High Efficiency Air Filters — — Impingement Separators —
Thermal Precipitation (used only for sampling)
— Mechanical Separators —
— Electrical Precipitators —

Terminal Gravitational Settling* [for spheres, sp. gr. 2.0]

In Air at 25 C. 1 atm. — Reynolds Number: 10^{-12} 10^{-11} 10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4}

In Air — Settling Velocity, cm/sec.: 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3}

In Water at 25°C. — Reynolds Number: 10^{-15} 10^{-14} 10^{-13} 10^{-12} 10^{-11} 10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4}

In Water — Settling Velocity, cm/sec.: 10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1}

Particle Diffusion Coefficient,* cm²/sec.

In Air at 25°C. 1 atm.: 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11}

In Water at 25°C.: 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12}

*Stokes-Cunningham factor included in values given for air but not included for water

Particle Diameter, microns (μ): 0.0001   0.001   0.01   0.1   1   10   100   1,000 (1mm.)   10,000 (1cm.)

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1. A micrometre (μm) is equal to 1/1000
    of a millimetre, or 1/25,000 of an inch.

2. Viruses are between 0.01 and 0.1 μm in
    size.

3. Bacteria are between 1 and 25 μm in size.

4. Fog droplets are between 5 and 60 μm
    in size.

5. Raindrops are between 400 and 5000 μm
    in size.

6. Particles approximately 10 μm in diameter
    are barely visible to the naked eye.

Aerosols are usually particles which range in
size from 10 μm to something less then 0.01 μm. Most
aerosols are considered to be less than 1 μm in diameter.

Particulates are responsible for two basic
types of air pollution problems:

1. Soils, corrosion, injury to clothing,
    property and crops as a result of
    deposition.

2. Adhesion of particulates to respiratory tissues
    with possible physiological impairment or
    damage. Particulates may include toxic
    substances, possibly carcinogens and radio-
    active materials.

Polluting particles are comp osed of a variety
of substances originating form the myriad activities
conducted by man. Because their size and, to a
lesser degree, their physical state influence their
behaviour so greatly, they are commonly identified by
the appearance and behaviour of the emission in which

they are contained. For example:

1. Smoke describes unburned carbonaceous
    particules mostly 1 micrometre in diameter
    produced as a result of combustion.

2. Fume indicated the solid particles under
    1 micrometre in diameter that are formed
    as vapours condense or as chemical reactions
    take place. Fumes are emitted by many
    industrial processes, including metal smelt-
    ing and refining, distillation and removal
    of solid impurities by boiling liquid
    materials and condensing the vapours.

3. Dust is a more general term than fume. When
    solid particles are more than 1 micrometre
    in size they are generally referred to as
    dust. Dust may be formed by natural proces-
    ses or in innumerable mechanical operations
    conducted at industrial and agricultural
    facilities.

4. Mist consists of liquid particles up to 100
    micrometre in diameter. They may be released
    in such industrial operations as spray-
    ing and impregnating, or formed by the
    condensation of vapour in the atmosphere.
    As mists evaporate, more concentrated liquid
    aerosols may be formed.

Aerosols tend to remain suspended permanently
in the air and are usually emitted either in aerosol
form or evolve from the fracturing or decomposition of
large particulates, or they form in the air from the
condensation and nucleation of gaseous contaminants.
They may be organic or inorganic in composition, and
may be liquid or solid. The smaller the aerosols the

more they behave like a gas. Aerosols, therefore, are not as readily deposited as the particulates and may be inhaled and exhaled with air. Aerosols are also important for their ability to reduce visibility through the process of light scattering.

Gases

A gas is a non-coherent state of aggregated matter, i.e., a fluid of freely-moving molecules tending to expand infinitely and to diffuse and mix readily with other gases. As pollutants, gases include a large variety of inorganic and organic gases which may have noxious, malodorous, toxic or corrosive effects, or which may have an effective smog-producing potential.

Organic Gases

Organic gases consist entirely of compounds of carbon and hydrogen and their derivatives. These include all classes of hydrocarbons (olefins, paraffins, and aromatics) and the compounds formed when some of the hydrogen in the original compounds is replaced by oxygen, halogens, nitro or some other substituent groups. The latter are the hydrocarbon derivatives.

The principal origin of hydrocarbons is petroleum, and the principal sources of emission of hydrocarbons and their derivatives are those related to the processing and use of petroleum and its products. Hydrocarbons are released to the atmosphere during the refining of petroleum, during transfer and storage of petroleum products, and during the use of products such as fuels, lubricants, and solvents. Derivatives of hydrocarbons can also be released into the atmosphere in connection with these processes and in connection with their manufacture and use. They can even be formed in the atmosphere as the result of certain photochemical reactions.

Hydrocarbons

The most important source, by far, of emission of hydrocarbons is the use of gasoline for the operation of motor vehicles. This source alone accounts for the major part of the total emission in heavily populated areas. Except for about 2% of the total, the balance of the hydrocarbon emission are divided between the petroleum industry and industrial and commercial users of organic solvents.

Two groups of hydrocarbon compounds are of great importance in air pollution. First, the olefin or ethylene series and then the aromatic, benzenoid or benzene series.

Olefins

The olefins are a group of unsaturated carbons. (Unsaturated compounds react easily with other chemicals). Most olefins in small concentrations appear to have no direct effect on animal life, although some cause a general reduction in plant growth. In addition, olefins take part in photo-chemical reactions with nitrogen oxides and several other classes of compounds.

Aromatics

Included in the aromatics are a number of compounds believed or known to be carcinogenic (cancer-producing). The most potent of these is benzpyrene (often written benzo(a)pyrene or 3, 4 benzpyrene). A primary source of these carcinogens is the incomplete combustion of organic materials. In fact, most polluting hydrocarbons are dis-charged into the air by incomplete combustion. And the

major source of this kind of contamination is the burning
of gasoline in automobiles.

Hydrocarbon Derivatives

The greatest part of hydrocarbon derivatives
emitted to the atmosphere results from solvent uses such
as surface coating, degreasing, and dry cleaning, and
other industrial and commercial processes. The balance
is included in the products of combustion of various
fuels and of the incineration of refuse. The substitu-
ted hydrocarbons emitted to the atmosphere by industrial
and commercial use of organic solvents include oxygenates,
such as aldehydes, ketones, and alcohols; organic acids;
and chlorinated hydrocarbons. Most hydrocarbon deriva-
tives associated with surface coating are oxygenates
whose presence can be related either to the solvent itself
or to the products of the partial oxidation involved in
the drying of the coated objects. The hydrocarbon deriva-
tives associated with degreasing and dry cleaning are
mostly chlorinated hydrocarbons. The derivates associated
with combustion, either of fuels or of refuse, are products
of incomplete combustion and are almost entirely oxygenates.
Thus, the composition of atmospheric emissions of hydro-
carbon derivates is currently about one fourth to one third
chlorinated hydrocarbons and two thirds to three fourths
oxygenates.

Hydrocarbons and their derivates are important
because of their ability to participate in the atmospheric
reactions that produce effects associated with photo-
chemical smog. The most reactive group, the olefins
(unsaturated hydrocarbons), can react with nitrogen
dioxide to produce plant damage, eye irritation, visibility-
reducing aerosols, and oxidants or ozone. Paraffins

(saturated hydrocarbons) can also react with nitrogen dioxide to produce all these effects except plant damage. Aromatic hydrocarbons, particularly those having various substituent groups, can react with nitrogen dioxide to produce a type of plant damage different from that usually associated with smog and produce all the other effects as well.

The hydrocarbon derivatives, particularly the aldehydes and ketones, and even some of the chlorinated hydrocarbons, can also react with nitrogen dioxide in the atmosphere to produce eye irritation, aerosols, and ozone. Further, some of the aldehydes and nitro derivatives are, themselves, lachrymators and some of the chlorinated hydrocarbons are rather toxic.

The hydrocarbons are further indicated because photochemical reactions in which they participate sometimes produce hydrocarbon derivatives such as aldehydes, ketones, and nitro-substituted organics, which in turn react to increase the production of smog effects.

Inorganic Gases

Inorganic gases include oxides of nitrogen, oxides of sulphur, carbon monoxide, and much smaller quantities of ammonia, hydrogen sulphide, and chlorine. The principal source of the oxides is the combustion of fuel for industrial, commercial and domestic uses; for transportation; for space heating; and for generation of power.

Oxides of Nitrogen

Nitrogen (N) is in itself a colourless, tasteless, odourless gas that constitutes 78 per cent of the atmosphere.

A number of oxides of nitrogen occur, but only nitric oxide and nitrogen dioxide are important as air contaminants.

The first, nitric oxide (NO), a colourless, somewhat toxic gas, is formed through the direct combination of nitrogen and oxygen from the air in the intense heat of any combustion process. Nitric oxide in the atmosphere is then able in the presence of sunlight to combine with additional oxygen to form nitrogen dioxide (NO_2). The oxidation of nitric oxide to nitrogen dioxide is very rapid at high concentrations in air, but is slow at low concentrations except in the presence of hydrocarbons and sunlight.

Since nitrogen dioxide is formed so readily by photochemical action, it is usually thought of as a product of the photochemical process. But actually it may be formed whenever nitric oxide is a by-product of sufficiently high burning temperatures, with or without photochemical action. It is also a product or by-product of a number of industries, including fertilizer and explosives manufacturing.

Thermo-generating plants which operate at high temperatures can also be a serious source of oxides of nitrogen. In these plants the amount produced increase to staggering figures as temperatures exceed 1 650°C. For example, in going from 540° to 1 650°C, the nitric oxide concentration increases 1 800 times, and in going from 540° to 2 200°C it increases 13 000 times.

Nitrogen dioxide is the only important and widespread pollutant gas that is coloured (yellow-brown). As a result, it can significantly affect

visibility. It has a pungent, sweetish odour detectable at 1 to 3 parts per million, fortunately a level seldom reached in polluted atmospheres.

Nitric oxide is considerably less toxic than nitrogen dioxide. It acts as an asphyxiant when in concentrations great enough to reduce the normal oxygen supply from the air. Nitrogen dioxide, on the other hand, in concentrations of approximately 5 ppm, can produce lung injury and oedema, and in greater concentrations, fatal lung damage. It is an insidious gas as fatal amounts may be breathed without significant discomfort, although high concentrations may produce moderate irritation and coughing at time of exposure.

Nitrogen dioxide reacts with raindrops or water vapour in the air to produce nitric acid (HNO_3), which, even in small concentrations, can corrode metal surfaces in the immediate vicinity of the source. Vegetation, too, can be injured when it grows close to factories handling large amounts of nitric acid. The nitrogen oxides present in the ordinary community's air, however, are probably always too low to damage plant life.

The dioxide, then, is heavily indicated as an undesirable constituent of the atmosphere, regardless of the type of air pollution problem under consideration. Nitric oxide is indicated too, because of its ability to produce the dioxide by atmospheric oxidation. Fortunately, no link between atmospheric concentrations of nitrogen oxides and actual injury or illness in humans or animals has been reported yet.

Oxides of Sulphur

Air contaminants classified as oxides of sulphur consist essentially of only two compounds, sulphur dioxide (SO_2) and sulphur trioxide (SO_3). The primary source of both is the combination of atmospheric oxygen with the sulphur in certain fuels during their combustion. The total emitted quantities of the substances are, therefore, directly related to the sulphur content and total quantities of the principal fuels used in a community.

The major oxide of sulphur that is produced in combustion is sulphur dioxide (SO_2), a heavy, pungent, colourless gas that dissolves easily in water vapour to form a solution of sulphurous acid (H_2SO_3). Sulphurous acid, mildly corrosive, is used as a bleaching agent in industry. It joins slowly with the oxygen in the air (or quickly if catalysts are present) to become the even more corrosive, irritating mist, sulphuric acid (H_2SO_4).

Sulphuric acid can also be formed by a different route. Sulphur dioxide can be oxidized directly (changed chemically by combining with oxygen) to sulphur trioxide (SO_3), which can be either a colourless liquid or a white solid aerosol. Sulphur trioxide is a likely product when combustion takes place with excess oxygen. The change is abetted by the catalytic action of some of the ash residue, especially the iron oxides that form on boiler tubes and walls. As sulphur dioxide leaves the smoke stack it usually diffuses rapidly, so that oxidation to sulphur trioxide takes place rather slowly. But, with time, sulphur trioxide can build up substantially and react very quickly with water vapour to form sulphuric acid.

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Primarily, gaseous oxides of sulphur in the atmosphere are significant because of their toxicity. Both the sulphur dioxide and sulphur trioxide are capable of producing illness and lung injury even at small concentrations, from 5 to 10 ppm.

Sulphur dioxide by itself also produces a characteristic type of damage to vegetation whereby portions of the plant leaves are bleached in a specific pattern. In concentrations as small as 5 ppm, sulphur dioxide is irritating to the eyes and respiratory system. It is colourless, with a characteristic pungent suffocating odour, and high concentrations can produce oedema, respiratory paralysis, and death, but become intolerable before reaching immediately dangerous levels.

Both the dioxide and trioxide can combine with particles of soot and other aerosols to produce contaminants more toxic than either alone. The combination of the dioxide and the trioxide with their acid aerosols has also been found to exert a synergistic effect on their individual toxicities. These mixtures were apparently responsible for the illness and death associated with the infamous air pollution incidents that occurred in the Meuse Valley, Belgium; in Donora, Pennsylvania; and, more recently, in London, England.

Other Sulphur Compounds: Hydrogen Sulphide, Organic

Sulphides and Mercaptans

Both thermal and catalytic cracking processes in oil refining operations convert the sulphur contained in the crude oil into hydrogen sulphide (H_2S) in the gasoline fractions. The same substances are also produced in Kraft paper mill processes. When hydrogen

sulphide is released to the atmosphere as a gas, it
manifests a characteristic rotten egg odour. Mercaptans
also exhibit varying types of strong unpleasant odours
such as garlic, decayed garbage, skunk or onions from
relatively small gas concentrations. Hydrogen sulphide
is detectable at 0.12 ppm and mercaptans from 0.001 to
0.041 ppm. H_2S will also discolour some painted surfaces
with lead pigments under humid conditions.

Carbon Monoxide

Carbon monoxide (CO) results from the incomplete
combustion of any carbonaceous fuel. Automobiles provide
a principal source as it comprises from 1% to 5%, or
more, of the total emission, depending on carburetor
adjustment. Automobile fumes constitute about 97% of
the total carbon monoxide emitted in a large metropolitan
area and this is the only important source of this pollu-
tant at ground level.

It is a colourless gas which has been described
as odourless to practically odourless. It is non-irri-
tating but causes dizziness, headache, weakness, heart
palpitation, staggering, confusion, nausea, vomiting,
unconsciousness, convulsion, weak pulse, slow respiration,
and death. It produces its damage by combining with
haemoglobin of the blood, so excluding oxygen from the
tissues, leading to asphyxiation of the cells, especially
nerve cells. Concentrations of 200 ppm and greater are
required to produce illness and death. It has been
detected in the atmosphere of various urban centres of
the world at concentrations from 10 to 150 ppm. Greater
concentrations have occasionally been measured in confined
spaces such as tunnels and large, poorly ventilated
garages. Atmospheric concentrations have not yet linked

to fatalities, but have sometimes been implicated in
short-term illnesses of traffic officers.

Miscellaneous Inorganic Gases

These include ammonia, hydrogen sulphide,
chlorine, and fluorine or fluorides. They are normally
only detected in trace quantities in the atmosphere but
all are toxic in small to moderate concentrations, and
the first three have unpleasant odours. Hydrogen sul-
phide can cause discolouration of certain kinds of paint;
ammonia can discolour certain fabric dyes and is corro-
sive to copper, brass, aluminum and zinc; chloride can
discolour certain fabric dyes; fluorine and fluorides,
especially hydrogen fluoride, are highly toxic, corrosive,
and capable of causing damage to vegetation, and illness
and injury to humans and animals.

Many other inorganic gases may be individually
or locally objectionable or toxic. These are of relati-
vely minor importance and will not be discussed here.

OBJECTIVES:

The trainee will be able to:

1. List and describe the four ways in
    which air pollution effects become
    apparent:

    a. Reduction in visibility
    b. Damage to vegetation
    c. Soiling and property damage
    d. Physiological reaction

EFFECTS OF AIR POLLUTION

As the concentrations of contaminants in the atmosphere increase, certain typical air pollution effects become apparent. These are:

1. Reduction in visibility
2. Damage to vegetation
3. Soiling and property damage
4. Physiological reaction

Reduction in Visibility

Visibility reduction is due to the concentration of aerosols in the atmosphere and indicates an air pollution condition in the same manner that the clouding or darkening of a liquid may be said to indicate pollution by impurities. Two types of air pollution occur which affect visibility:

1. Sky darkening
2. Haziness or light scattering

In the former, the sky darkens and visibility is reduced by the physical obstruction of the sky illumination, as a result of clouds of contaminants and plumes of smoke and fumes from sources of pollution. In the latter, a haze evolves from atmospheric reactions which alters sky illumination by scattering the light. The blue colour of the sky, it should be noted, is the result of the mass uniform scattering of light from the molecules of atmospheric gases. Similarly the colour of the sky is altered by pollution hazes depending on the size of the aerosols relative to the wave length of light. Aerosols of a size between 0.4 and 0.9 μm are most effective in light scattering. (400 to 700 nanometre).

The nuisance value of visibility reduction
appears to be relative to the climate, geography, popu-
lation density and heights of structures, and the
viewing point of the average observer. In the Los
Angeles area the maximum visibility possible from the
sea to the mountains is sometimes of the magnitude of
55 kilometre.   During a smog attack this visibility
is reduced to less than 8 km.

Visibility reduction is an indication of pollu-
tion accumulation and its measurement is one of the
means by which pollution intensity is determined. Visi-
bility records can be used to show daily, weekly, monthly
and yearly variations, and reflect the changes which
take place in weather, the industrial economy and the
effects of control practices.

When the sky is darkened by air pollution it
must also be remembered that the amount of available
sunlight reaching the ground is being considerably re-
duced, and sunlight is essential to human and plant
life.

Damage to Vegetation

Injury and disease to sensitive forms of life
such as crops and plants resulting from air pollution
have been clearly established. Injury can range from
reduced growth and yield to complete plant destruction.
The effect air pollution has in reducing available sun-
light for vegetation is harmful in itself, but certain
air contaminants are capable of causing bleaching, dis-
colouration, stippling, stunting of growth, lesions,
cell damage, spotting, pitting, drooping, defoliation,
etc. Some forms of vegetation respond uniquely to

concentrations of certain contaminants, a fact which
have the following implications for the study of air
pollution.

1. Damage to any form of life serves to warn man of
   the presence of toxicants which may also adversely
   affect human health, cause crops grown for human
   consumption to become unmarketable or inedible,
   as well as poison foraging cattle.

2. Damage to plants may indicate the chemical reactiv-
   ity of the air.

3. Economic damage sustained by commercial growers of
   plants and crops in polluted areas may point to
   the need for research and control to remove the
   suspected contaminants from the air, or the un-
   desirability of growing sensitive crops.

The main airborne pollutants that injure plants
are sulphur dioxide, fluorides, and oxidants. On
occasion, chlorine, ammonia, ethylene, and particulate
matter have caused injury. Any pollutant which injures
vegetation is a phytotoxicant.

Toxic gases enter leaves via stomata (micro-
scopic openings in the leaves where normal exchange of
the gases oxygen and carbon dioxide occur). Inside the
leaf the pollutant interferes with the metabolism of the
cells causing leaf injury.

The injury may become visible in a short time
and take the form of necrotic lesions (dead tissue) on
the margins, or between the veins of the leaves. In
the necrotic areas the cells are killed and the tissue
collapses and dries to an ivory or reddish-brown colour.

The injury may develop slowly and become manifest as a yellowing, or chlorosis, of the leaf. The chlorotic tissues do not collapse but gradually lose their green colour.

The physiological processes of the plant may become upset, and there may be a reduction in the growth of various portions of the plant. Repeated injuries may result in the death of the plant.

The symptoms of injury caused by air toxicants are very similar to those of injuries caused by disease, insects, adverse weather, poor nutrition or mismanagement, and require diagnosis by specialists.

Examples of types of damage observed are as follows:

1. Silvering and bronzing of the undersides of many broad-leaved plants, particularly annuals, as a result of the presence of unsaturated hydrocarbons.

2. Retardation of growth of many plants, as a result of the presence of plant toxicants.

3. Stippling on grapes and tobacco, and bleaching on the upper surfaces of older leaves of some plants as a result of ozone.

4. Bleached areas between veins of some plants as a result of sulphur dioxide, which is capable of damaging plants at relatively low concentrations.

5. Other forms of damage to plants include accumulative poisoning from fluorine and lead compounds, damage to leafy vegetables and flowers from sulphuric acid aerosols, etc.

Soiling & Property Damage

One of the first material effects of air pollution is the soiling of clothing, buildings and properties. A familiar annoyance is the soiling of clothing and textile materials exposed to air containing smoke, soot and dust. Air pollution has a direct influence on the cost of cleaning and laundering, on the marketability of merchandise, and the cleaning of buildings.

Air pollution may also damage property. The damage is usually of a cumulative nature, tends to shorten the durability of materials exposed to the atmosphere, and is generally caused by the inter-action of the contaminants with the surface or the protective coatings of materials in the form of:

1. corrosion (chemical or electro-chemical reaction

2. erosion (mechanical abrasion of surfaces by wind-blown materials).

3. oxidation (such as rubber cracking from ozone and other oxidants present in the atmosphere).

4. spotting (contamination of surfaces by paints and oil droplets, carbon spheres and fly-ash).

Everyone has seen some example of this type of damage, maybe metal corrosion, damage to stone and masonry, or excessive cracking on rubber tires, damage to automobile paint work, etc. The economic impact is quite significant.

Steam and sand-blast cleaning of exteriors of large buildings is a maintenance expense which increases as air pollution increases. Frequent cleaning of clothing and repainting of residences are other examples of the numerous items to consider in estimating economic loss from air pollution.

Physiological Reaction

Some years ago the United States' Surgeon-General stated, "There is no longer any doubt that air pollution is a hazard to health."

The United States' National Air Pollution Control Administration, in its publication No. AP-49, 1969, states: "Analyses of numerous epidemiological studies clearly indicate an association between air pollution, as measured by particulate matter accompanied by sulphur dioxide, and health effects of varying severity. This association is most firm for the short-term air pollution episodes."

The effects of air pollution on health vary with the age and physical condition of each individual, the nature and degree of concentration of the pollutant or pollutants, and the duration of exposure. The very young, the aged, and those with throat or lung sensitivity are specially susceptible. The incidence of bronchial and respiratory ailments is invariably high in large cities and prolonged exposure to even moderate concentrations of pollutants is deemed by medical authorities to be an important factor. Serious pollution episodes in which severe illnesses have been blamed on air contaminants have occurred in the Meuse Valley in Belgium, in Denora, Pennsylvania, and on a number of occasions in New York City, and in London, England.

Denora, an industrial community in a deep valley about 50 Km south of Pittsburgh, provided a dramatic instance of a number of air pollution incidents in the United States.

There, during a five day calm in October 1948, air pollutants from mills, smelters and acid plants accumulated and thousands of illnesses were blamed on the occurrence, with several hundred hospitalized and twenty deaths. Over one hundred and thirty separate law suits were filed and, as a result of ensuing public outcry, in 1950 a comprehensive technical conference on air pollution was convened in Washington at the highest official level.

Denora's problem occurred during a temperature inversion with no air movement to dilute and disperse the pollutants. Similar circumstances prevailed in London, England, in 1952, and over a period of days the concentration of air pollutants in that area increased alarmingly, as did the incidence of cases of death and illness from various respiratory diseases, during and after the episode.

It is known from the results of such air pollution disasters, and from the toxic potentials now found in the atmosphere in many cities, that concentration of air pollution can be reached in the atmosphere which may cause irritation of the eyes and the respiratory tract, headache, nausea, allergy, illness and even death, and that continuous daily exposure to polluted air may cause life-shortening diseases.

Much remains to be known about the long range
effects of low concentrations, particularly their in-
fluence on such respiratory diseases as emphysema, asthma,
and lung cancer. Although data is insufficient to prove
such relationships, most informed authorities on the
subject believe that they exist to some degree.

OBJECTIVES:

The trainee will be able to:

1. Briefly describe why a high per-
   centage of sulphur dioxide in the
   atmosphere is harmful to surfaces
   and materials;

2. Explain the significance of high
   oxidant levels and its effect on
   rubber;

3. Describe the effects of fall-out
   of acid particulates on materials;

4. Name the two principal caustics in
   common use and describe the effects
   of the more significant one on
   materials;

5. State why the important pollution
   properties of paint droplets are
   the drying rate, the distance trav-
   elled and the degree of surface
   adhesion.

6. Briefly describe the operation of
   the various types of paint spray
   booths, and the simple control
   measures necessary to maintain
   their efficiency;

7. Explain the importance of wind di-
   rection in tracing the source of
   liquid particulates;

8. List the basic information headings
   required in a major investigation of
   a liquid particulate problem:

   a. Frequency and time of day con-
      tamination takes place,

   b. Length of period of contamination,

   c. When contamination was first
      noticed,

   d. Prevailing wind patterns for the
      area.

AIR CONTAMINANT DEPOSITS CAUSING DAMAGE AND STAINS

GENERAL

Stains refer to the damaging or soiling of property resulting from the inter-action between air contaminants and the surfaces or surface coatings of materials. In complaint problems, typical stains include pitting, incrustation, etching, spotting, buckling, abrasion, corrosion and other forms of deterioration.

Stains generally result from the deposition of mist droplets or liquid particulates, usually of an acidic or caustic nature, although some solid particulates and aerosols may also exhibit staining or damaging properties. The type of problem found as a result of mists depends on the nature of the industrial economy and the climate, particularly with respect to sunlight and humidity. Humidity increases the rate of corrosion, as well as influencing mist production. Sunlight induces photochemical reactions and catalytic reactions leading to the formation of oxidants. A typical corrosive atmosphere found in our urban areas today is one which contains a high degree of sulphur dioxide. Sulphur dioxide in the atmosphere, as we have noted, readily converts to other aggressive substances. Hydrogen sulphide and sulphuric acid will attack lead-based paints leaving a brown to black discolouration. Sulphuric acid, also, will attack a variety of substances, including building materials such as carbonate-bearing stone, zinc gutters, canvas, copper wire and surface coatings.

Cracking of rubber is an indication of oxidant levels which normally are highest during the period from May to September; this is borne out by the effects package studies carried out in Ontario. Other parts

of these studies included the tarnishing of silver
plates, damage to nylon fabrics, and corrosion meas-
urements over different periods of time on steel and
zinc plates.

Local problems resulting from liquid particu-
lates tend to fall into two catagories:

1. Acid and caustic stains causing some form
    of permanent damage to property.

2. Spotting by paints, oil, greases or other
    materials which adhere to surfaces without
    necessarily damaging them and which can be
    removed.

DAMAGE BY ACIDS AND CAUSTICS

A frequent type of complaint encountered concerns
the discolouration and damage of lead-based paints,
particularly automobile finishes, by acids. Acid
stains usually appear as brown-to-black irregular pin
pricks to spots which range in size to approximately 5
mm in diameter, shaped in the cross-section of the
depositing mist droplet. Cars so damaged exhibit a
spotty appearance, particularly on the upper surfaces
of the vehicle. In cases where acid deposits are found,
the source is usually located close by. Virtually all
acids in appropriate concentrations by their nature
contain properties of a potentially damaging character.
They will attack and discolour materials; dissolve or
corrode metals, oxides and carbonates; burn or ulcerate
skin; and irritate the eyes. Some acids like phosphoric
acid, used in the production of fertilizers, ceramic and
glass products, phosphoric anodizing, petroleum refining,
catalysts, and cleaning of metals, are capable of

attacking canvas and aluminum sidings, and will cause
incrustation on automobile finishes which, however,
can be wiped off. Nitric and nitrous acids, which
may be emitted as a brown cloud in by-product
manufacturing or fertilizer processing, or explosives
plants, may also give off irritating corrosive mists.
Hydrochloric acid, which is emitted as a by-product
in the manufacture of chlorine products; used in the
manufacture of scale solvent; in making swimming pool
acidic adjustments; in pickling processes, etc., will
attack metal fencing and similar materials.

The three most important acid mists are chromic,
sulphuric, and hydrofluoric acids. These acids are
not usually emitted as a regular consequence of pro-
duction cycles, but usually as a result of accident or
equipment failure. Most plant operators, for reasons
of health and safety, attempt to maintain careful
control of acid handling. When control equipment fails,
acid particles build up with moisture on control surfaces
and are dumped or exhausted into the atmosphere under
draught pressure.

Chromic Acid

In addition to attacking paint, chromic acid
mists are also capable of causing eye irritation and
offensive ("dead cat") odours. The primary source of
chromic acid mist is inadequately controlled electro-
lytic chromium plating tanks. Chromic acid mist results
from the fact that hydrogen and oxygen bubbles, released
electrolytically, pick up particles of the acidified
solution formed in the film on the surface of the tank.
Generally speaking, such problems arise from hard chrome
rather than soft (decorative) chrome plating operation,

since in the former greater current densities and high bath temperatures are applied, thus creating more side reactions and increasing the rate of emission of liquid particulates. Typical solution compositions for both soft and hard chrome plating are 3.3 ml of chromic acid per litre of solution. Typical current density and bath temperature for soft chrome are 125 mA/cm^2 at 40°C and for hard chrome, 235 - 310 mA/cm^2 at 50°C. Such operations can be controlled by a commer-cial mist inhibitor or surface active agent, which breaks up surface tension and keeps the particles which would ordinarily form a surface film in solution, or by the use of wet collection or dry-type filters.

Sulphuric Acid

Because sulphuric acid is one of the most economical of the inorganic acids, it is widely used in industrial operations to remove sulphur and unsaturated compounds, in battery manufacturing, for purification, and in many refinery and plating processes. Sulphuric acid mist droplets are capable of producing brown to black discolouration and pitting on lead-based surface coatings. Another familiar effect is the deposition of sulphuric acid either directly or indirectly in the troughs formed in the slack of canvas awnings. Sulphuric acid will destroy materials wherever it is permitted to accumulate.

Hydrofluoric Acid

Hydrofluoric acid readily fumes and is capable of severely attacking skin, poisoning leafy vegetables and flowers, and pitting glass and metal. It is used in the

commercial production of fluorides, in metallic
aluminum and metal fluorides, insecticides and laundry
products. It is prominently used in the etching,
frosting and polishing of glass, and as a catalyst in
the conversion of olefins and isoparaffins in alkyla-
tion plants in refineries, as well as in the pickling
of steel alloys. It will distinguish itself from the
other acids by causing comprehensive damage. When it
attacks an automobile, for example, it attacks the
paint, chrome and glass. Because of the high degree of
activity of this contaminant, and its danger to health,
equipment and vegetation, it is handled and controlled
carefully by maintenance in a dry state or in such
dilute quantities as to avoid causing damage in the
vicinity of its use. Because of the interest in its
control, hydrofluoric acid is more likely to create a
one-time problem as a result of equipment breakdown,
particularly from an alkylation plant, rather than a
continuing chronic problem. It may also occur as a
by-product in the manufacture of rocks and phosphate
when sand used in its control is spent. (Hydrofluoric
acid reacts with silica, or sand, to form hydrofluo-
silic acid.)

Caustics

Caustics fall into the chemical category of
alkalies, that is, they are capable of neutralizing
acids as well as providing a detergent, and, in some
caustics, an etching action. Principal caustics are
sodium carbonate and sodium hydroxide, the latter being
more commonly used. Sodium carbonate is used in large
scale chemical manufacturing, the manufacture of glass,
soap powders amd detergents. Of the caustics, sodium
hydroxide is perhaps the most significant since it

attacks the skin, is strongly alkaline, and very
soluble. It is employed in the petroleum industry,
in the viscose process for rayon manufacturing, and
the manufacturing of chemicals and soaps.

In sufficient concentrations it will attack
paint, glass, and aluminum, and cause pitting, etching
and buckling. The etching properties of this chemical
are put to use in the aircraft industry in a chemical
milling process which reduces the thickness of preformed,
stress-relieved aircraft parts made of aluminum, magne-
sium, stainless steel and titanium. This chemical pro-
cess performs milling jobs such as shaping and tapering,
and can mill surfaces at the rate of 25 micrometre per
minute. The chem-mill bath consists of a caustic
etching solution of 7% sodium hydroxide by weight, water,
and a trace of sodium aluminate, and is heated to about
$90^{\circ}C$. The sodium hydroxide mists are usually vented
by means of slot hoods to a water scrubber. If uncon-
trolled, chem-milling may cause a problem.

SPOTTING BY PAINTS AND OTHER MATERIALS

Complaints which have to be dealt with in this
category result from the deposition of paint, oil,
grease droplets or other materials which adhere to
surfaces or surface coatings without necessarily
damaging them. Quite often such deposits are readily
removed with water, thinners, or detergents. In some
cases, surfaces may require rebuffing and repainting.
The droplets of this type are generally significantly
larger or heavier than those described previously, and
enter the atmosphere directly from spray or atomizing
devices, and occasionally by entrainment and ejection
from wet collection equipment or blower exhaust systems.

They frequently contribute to the contamination of automobiles, house sidings, clothing etc., in the community in which the spraying is performed.

Paint Spots

Paint spots are mist droplets of paint pigments and binders which deposit in a liquid state and adhere to surfaces. Paint mists are frequently emitted from paint spraying operations usually conducted under high-volume production conditions. With average wind movement and humidity, all paints tend to fall out within the first 50 to 150 m from the source, with the exception of certain metallic pigmented paints, such as aluminum, which may travel as much as one kilometre.

The important pollution properties of paint droplets are the drying rate, the distance travelled, and the degree of surface adhesion. The speed at which paints dry depends primarily on the rate of evaporation of the volatile portion (solvent) contained in the paint. Paints containing slow-drying solvents may travel in the air as mist droplets which then dry after deposition on surfaces. Paints which require heating or baking for drying are generally of this type. Baking enamel, for this reason, is often implicated in over-spray complaints. Primers, sealers and water-based paints, although emitted as a liquid are deposited as a solid, and have the appearance of coloured dust, depending on the relative distance between the source and the surface. Zinc chromate primer, for example, is yellow-green, while lead primer is red.

Paints also give off characteristic odours
usually due to the evaporation of the organic solvents
(varnishes or oils) contained in the vehicle of the
paint. The principal vehicles used are oleoresinous
varnishes, alkyds, dispersion resins, malamine, and
phenolics. An odour problem from paint is generally
not significant unless complaints are very close to
the source.

The uses and relative pollution properties of
commonly used paints are described in Table **3-1** Drying
rates, it should be noted, vary considerably within any
category of coating, depending on the initial drying
or "flash off" of the specific solvents. Those shown
in Table 3-1 are for typical industrial situations.

Complaints generally arise from the use of paints
only when they are sprayed or atomized, usually with
standard pressure spray guns. Paint spraying may be
conducted in the open or in one of several types of
specially constructed paint spray booths. "Open spraying"
is conducted outdoors on structures so large that it is
impractical or uneconomical to utilize a paint spray
booth; for example, spraying of houses, structural
steel beams, etc. However, most spraying, for reasons
of economy and safety, and Fire and Health Department
restrictions, are conducted within a suitably designed
paint spray booth. The article to be coated is placed
or mounted in the booth whether on a pedestal or conve-
yorized assembly unit, and is sprayed by an operator
or automatic spray equipment.

The types of paint spraying operations employed
depend on the nature of the material to be coated -
wood, plastic, metal; the quality of the surface, i.e.
smooth, rough, porous, etc.; and the quality of the
surface coating desired, i.e. hardness, permanence, lustre,
etc. Woodworking, metal fabrication plants, and automobile

TABLE 3-1

Relative Pollution Properties of Commonly Used Paints

Coating	Use	Drying Rate	Removal
Clear lacquer	Used for wood and metal finishing and as sealer	Fast, air drying.	Very light and volatile. May be removed with lacquer thinner.
Pigmented lacquer	For painting automobiles, or metal surfaces, for rapid drying (alkyd resin)	Fast, air drying	With lacquer thinner
Lacquer enamel	Same as above, but bake dried	Bake dry, slow air drying.	With lacquer thinner
Synthetic enamel	Automobiles, refrigerators, stoves, lighting fixtures,etc	Fast-slow air drying.	With lacquer thinner
Primer	Undercoating may use all types of resins and pigments such as red lead & zinc chromate.	Very fast drying	Usually dries to dust. May be easily rubbed off.
Clear Sealer	Non-pigmented primer	Fast to slow	Same as above, may be removed.
Water-based paint.	Emulsified with water; mannikins, papier-maché, houses, etc.	Very fast drying.	Same as above.
Metallic pigmented enamel	Painting large storage tanks, an economical protective coating.	Usually medium-slow, light, may travel long distances.	Aluminum-metallic paint adheres; may be removed with mineral spirits or thinner.

and aircraft manufacturing and repair plants are
most generally encountered in air pollution problems,
although paint spraying operations tend to be common
to the entire industrial economy. Woodworking tech-
niques include conditioning of the article by means of
sanding, application of sealer, stain (either oil or
water-based) and application of a final coat of lacquer.
In plants manufacturing metal products, articles to be
coated may be conditioned by degreasing with vapour
solvents and buffing, and primers may be applied as
undercoating. Lacquer-enamels, synthetic enamels or
metallic pigmented enamels are applied as a finished
coating. To improve the properties of adhesion, hardness
and resistance to chemical deterioration, painted
articles such as automobiles and other metal products
are baked or force-dried in ovens at temperatures
ranging from 65°C to 260°C.

In small plant operations, one booth may be used
for application of preparatory and final coatings, whereas
in large conveyorized assembly-line plants a paint spray
booth may be utilized for each type of spray operation
conducted.

The design of the booth, the equipment used, and
the type and volume of paint sprayed affect directly
the amount of air contaminants emitted. Booth design
generally falls into two categories, dry and wet types.

The simplest dry-type booth is merely an enclosed
structure equipped with a blower motor fan and stack.
The size of the booth depends on the size of the object
to be sprayed, and the blower motor and fan diameter
are rated to handle the volumes of paint sprayed and the

dilution necessary to keep the air in the booth clear.
The amount of paint mist entering the exhaust flow
after spraying depends on the size and nature of the
article being sprayed. A large flat article will retain
most of the spray whereas smaller objects, or those
which are gridded or perforated, result in greater
overspray.

Although the walls and ceiling of the simple
dry-type booth retain some of the overspray, most of
the mists and vapours are drawn out through the blower
systems to the outer atmosphere. Primarily used to
balance the air flow, not to reduce emissions of these
contaminants, flat metal panels, or baffles, are con-
structed as impact surfaces at approximately right
angles to the air flow entering the outlet of the
booth. Depending on the percentage of the cross-section
of the exhaust outlet obstructed by the baffles, a
proportion of the overspray is deposited and retained
on the baffles.

A more advanced type of booth employs filters
packed with a dry filter medium such as glass fibre,
fine wire, metallic screening, or crimped paper. These
are constructed in banks breeching the exhaust passages
of the booth. The efficiency of such filtering media
is relatively high for all paint particles, but not
for solvents.

A more efficient design of booth is of the wet-
type. This type is a special form of water scrubber
constructed in the form of a recirculating waterfall
curtain, which entrains the paint mist before it is
exhausted to the outer atmosphere. The paint particles
are then scrubbed out of the flow by detergent, are

collected in a settling tank, and the water recirculated. The more advanced of these booths are capable of collecting practically all types of liquid particulates, but some odours will be emitted (giving some indication of efficiency).

Known solvent recovery processes make some use of condensation, compression, absorption, distillation, or adsorption principles. Organic solvents used in coatings are not controllable by filters, baffles, or water curtains. In view of the small solvent vapour concentration in the airstream from the spray booth or applicator hood, the only economically feasible solvent control method is adsorption. Use of activated carbon has shown efficiencies of 90% or more to be possible, provided particulates are removed from the contaminated airstream by filtration before the airstream enters the carbon bed.

The effectiveness of the control features of all booths depends on proper operation and maintenance. Skilled operators attempt to reduce unnecessary overspray, not only to prevent air pollution but to conserve paint. Pressure guns are operated only when necessary, and with such skill as to accomplish an efficient and uniform coating of the article.

Booths utilizing dry-type filter media will require that filter media be changed or replaced whenever there is a significant drop in draft pressure. Agglomerated contaminants in neglected or overloaded filter media will be forced into the atmosphere by draft pressure. Wet booths require constant recirculation of water and the use of a suitable chemical detergent to keep the curtain flow clean. Periodic

cleaning of the booth is necessary to prevent stoppages
in drainage and pumping systems which otherwise might
result in exhausting portions of the contaminated
solution into the atmosphere.

The design standards which must be met by paint
spray booths are determined both by engineering calcu-
lation and empirically in the field. The amount of
contaminants emitted into the air is readily determined
from the estimate of overspray, production quantities
of paints and thinners used, the scrubbing or filtering
ratio, indraft and crossdraft velocities as well
as the volume of air m^3/s moving through the control
sections of the booth.

Other Materials

Other spotting, sometimes similar to acid or
paint stains, can occur from a variety of industrial
or non-industrial sources.

Oil droplets on property can occur from several
sources - from malfunction at a refinery, high volume
oil-quenching operations, and jet and other aircraft.
Asphalt droplets may also occur from paving, roofing
equipment, or asphalt saturators.

Another source of liquid particulates arises
from the malfunctioning of collection equipment, par-
ticularly water scrubbers and wet filters, when par-
ticles entrained in the liquid media on wet walls,
impact surfaces, or baffles are ejected into the
atmosphere. This may occur accidentally from spray
towers, roto-clones, and even electrostatic precipitators.
Asphalt mists have been emitted from scrubbers and
control equipment serving asphalt saturators. This is
called reintrainment.

Occasionally, mud-like particles are emitted from wet collectors serving sand conditioning equipment in foundries.

Some more unusual problems can be encountered from natural sources, such as spots on houses and cars resulting from bee droppings. These have a characteristic light to dark yellow, orange or brown appearance, round or oval on horizontal surfaces, or streaks on vertical surfaces, with a waxy consistency when fresh. On aging, these spots become dark grey-green or dark brown in colour, are brittle and easily removed from a surface by scraping with a fingernail. They can be washed off with water, though not water soluble. As car surfaces, for example, frequently appear peppered with spots, these spots are often mistaken for stains resulting from industrial equipment.

Another type of complaint which arises at infrequent intervals describes small colourless sticky spots on property surfaces, usually the upper surfaces of automobiles. Investigation usually reveals that the car has been parked under a tree for some time. The deposits on the surface are the droppings from certain aphids which feed on the leaves of the trees.

Tracking Liquid Particulates

Because air-borne liquid particulates do not travel nearly as far as do odours, they will generally settle out in the neighbourhood close to the source of the mist. This particular property of liquid particulates, taken together with the fact that they can be sampled, is of great assistance in tracking down sources since sampling equipment or test panels can be used.

When the source is unknown, an estimation of
wind direction may be required. This may be accomp-
lished by a study of paths of deposition. If one side
of an automobile or a house is habitually contaminated,
the wind direction may be inferred. The interview
with the complainant should attempt to establish, if
possible, the wind direction at the time of contamina-
tion. If this is impossible, the inspector should
attempt to establish the time the contamination took
place, so that he can inspect the premises to determine
wind patterns for himself. In complex cases involving
heavily industrialized communities with many possible
sources, or where contamination does not appear to be
localized according to wind direction, the inspector
should plot a wind rose showing the direction from
which the wind came, the time intervals, and the rela-
tive intensity. This information can then be used to
plan reinspections and to determine the possible loca-
tion of test panels should they be required.

Most sources of liquid particulates can be
located by downwind tracing of the trail of fallout,
or areas of contamination. If the contaminant has been
identified, a given source may be shown to exist if the
contaminated area is within the probable range of travel
or fallout of the air comtaminant; if the air contam-
inant is observed or detected emitting from the source
in such quantities as to make contamination in the
affected area probable; and if no other sources can be
accounted for.

Once a plant is suspected, roof areas adjacent
to stacks and vents should be observed for stains,
coating, and other deposits which have accumulated.
The extent of the damage, and the degree of deterioration,

decay, erosion, and general filth on the deposited
material, should be compared with the total time the
equipment or process has been in use, and that compared,
if possible, with the extent of recent damage. The
over-riding path of such deposition should also indi-
cate the general direction contaminants have travelled
in the atmosphere, and may be lined up with the complaint
area in the community.

If no specific source is suspected, or more
than one source is possible, a major investigation may
be required, particularly if the damage from contami-
nants is serious and widespread. It is necessary to
determine the boundaries of the damage in order to
establish the range of travel. Once that is established,
inspections of industrial facilities can be concentrated
in the suspected area. The following should be deter-
mined from observation, testing and interview:

1. Frequency and time of day contamination
    take place
2. Length of period of contamination
3. When contamination was first noticed
4. Prevailing wind patterns for the area

In complex cases a sketch or map should be
drawn including the above information and indicating:

1. All possible plants, equipment and their
    distances from contaminated area

2. All areas affected, with notation as to which
    areas are most frequently affected, and their
    distances and directions from suspected sources.

3. Pertinent addresses, such as point observations and complaints

4. Location of test panel or fallout jar stations

When fallout jars or test panels are necessary, they may be posted or stationed in the following manner:

1. On or near contaminated objects, such as automobiles or house sidings

2. If necessary in 360° circle around contaminated area to determine the path or trajectory of the contaminant, unless an inspection of the contaminated area already discloses the general pattern of disposition

3. Posting of one or more panels horizontally or stationing fallout jars as an indication of general fallout since some contaminants may travel long distances

4. Posting panels or stationing jars in possible lines of travel or contaminants from possible sources

5. Panels or jars should be systematically numbered and show dates of exposure. Exposure may be expressed in terms of minutes, hours or days.

6. Panels and fallout jars should be stationed and removed in a manner which will show time of day contamination takes place. The pattern for change may be based on a study of wind movement for the area.

SOLID DEPOSITS

By deposits we refer specifically to particles
of solid materials which settle out of the atmosphere or
impact on surfaces. These are fine materials which are
substantially in excess of one μm in diameter and
have a relatively fast settling rate, such as dust, ash,
minerals, grains, powders, flour, etc., and are large
enough to be seen with the naked eye. Small invisible
particulates do not generally enter into complaints,
unless they react chemically with surfaces to form
visible stains, abrasions or pittings. Complaints made
against deposits concern the littering, soiling qual-
ities of deposits, and the time and the expense required
to keep property free of them. Deposits may also con-
taminate material such as clothing and nylon stockings,
or enter into commercial or industrial processes as
impurities. For this reason one industrial plant might
complain of another about the contamination of its
product by dusts or solid particles. Complaints are
received concerning the chronic contamination of swim-
ming pools from fly-ash or soot from incinerators or
boiler plant located nearby. Such deposits frequently
collect in rain gutters, window sills, sidewalks, porches,
curtains or clothes.

The sources of solid deposits are extremely
numerous. Dust is created by almost every commercial,
domestic and industrial activity. Dusts are produced
wherever materials are ground, pulverized, crushed,
destroyed, scraped, milled, conveyed, etc. Deposits
entering into significant complaints, however, most
likely originate from the "dusty" industries, i.e.,
wherever dusts, grains, minerals and other solid
particles are either manufactured or handled in large

volumes, or evolve as production waste. The "dusty" industries include grain and feed mills, mineral processors, fertilizer plants, pottery and ceramic manufacturing, hot asphalt and concrete batch plants, cement manufacturers, the roofing industry (mica, talc and crushed rock), woodworking industries (sawdust) and others. Handling and production equipment found in these industries include hammermills, pulverizers, crushers, bagging machines, shaking, classifying and grading devices, batching equipment, bucket elevators, air conveyor systems, aggregate driers, loading hoppers and scales, sanding equipment, shot blast booths, etc.

Even when control devices are installed, dust emissions may arise from leaks in equipment and conveyor systems, which should be checked for emissions. When a complaint is registered against a dusty industry, the officer should make an inventory of all the equipment, and make a flow chart to check out all possible points of dust emission.

The methods employed for tracking solid particulates from unknown sources are the same as those applied to liquid particulates. Solid particulates, however, are more readily traceable due to the trails, drifts or piles they tend to leave on the ground.

Where no immediate source is apparent in the community, it may be necessary to look for large sources located at considerable distances from complainants, such as steam-generating plants, ships, industrial incinerators, etc., especially when such dusts can be carried by strong prevailing winds, usually incoming shore breezes. A study of the micro-meteorology of the area will help locate a probable source area.

INDUSTRIAL ABATEMENT –   METEOROLOGICAL ASPECTS
AIR MANAGEMENT

OBJECTIVES:

The trainee will be able to:

1. Describe briefly the two main ways
    in which the dispersion and dilution
    of contaminants takes place, and
    the relevant factors which assist
    or retard these processes;

2. Describe a temperature inversion
    and its possible effects on a
    large city;

3. Explain what is meant by the term
    "smog";

4. Explain what is meant by the term
    "photochemical smog".

METEOROLOGICAL ASPECTS AND MEASUREMENT OF AIR POLLUTION

Meteorology

Weather and climate influence to a great degree the level of air contaminants in the community. Unfavourable weather conditions permit a build-up of contaminants and, alternatively, dispersions tend to lower levels.

Dispersion and dilution of contaminants are activated by complex atmospheric forces such as the stability of the air mass, and the wind direction and velocity. Even when contaminant emission rates to the air are constant, concentrations at ground level may differ markedly from hour to hour with meteorological changes. The pollution emitted by the source may be dispersed in two ways:

1 Horizontally

Generally, the higher the wind speed, the greater the dispersion and the lower the ground concentrations. Direction is important in as much as the prevailing wind indicates the area of heaviest pollution in any city, e.g., East end as compared to West end.

2. Vertically

The temperature profile of the atmosphere determines the vertical dilution of contaminants.

Windspeed

Wind speed is a particularly important factor as generally the lighter the wind the greater the concentration. The effect is very pronounced at a rate of 10 Km per hour or less. However, high winds are not

always beneficial as they can cause high pollution by
aerodynamic down-wash of stack effluents, or prevent
normal upward thermal rise of hot gases. The wind
pattern of an area is extremely useful in determining
the movement of contaminants.

Turbulence

Turbulence is another contingent factor and may
be either mechanical or convective. The former is rela-
tively small-scale in effect, being caused by obstructions
to wind movement by buildings, hills and trees. The
latter results from a regular heating and cooling of the
land and air. The transfer of heat from the sun to the
atmosphere is caused by radiative heating and cooling of
the ground during the day, the conductive heating and
cooling of the air layer in contact with the ground, and
the convective transfer of heat by air movement. Warm
air being less dense is displaced by cooler air and rises
causing overturning and movement vertically. During
stable conditions, when the temperature of an air mass is
fairly uniform, turbulence is at a minimum. The relatively
extensive air reservoir over any community is capable of
accepting and dispersing large quantities of air contami-
nants without causing adverse effect. Problems arise
when the air is still.

Ordinarily, temperature decreases with elevation
above the earth. When the reverse occurs, a temperature
inversion exists, resulting in stratification of the
atmosphere. During an inversion, vertical mixing and
turbulance are restricted, confining contaminants to a
thin layer of the air mass near the ground. Resultant
accumulations if prolonged for 5 or 6 days can be disas-
trous, as we discussed in our general introduction.

The change of temperature with height in the atmosphere is called the lapse rate of temperature.

The wind and lapse rate of temperature control the dispersion of a plume into the atmosphere.

Winds which vary their direction spread a plume out over a wide angle. (Figure 4-2)

Stronger winds dilute the plume faster.

Stronger winds also cause the plume to bend over into the horizontal faster and reduce the effective stack height.

The effective stack height is the distance from the ground to the level at which the centre of the plume becomes horizontal--the sum of the actual stack height and the plume's rise above the stack.

Factors that increase the plume rise and the effective stack height are the exit velocity of the plume from the stack and the difference in temperature between the plume and the air at the top of the stack.

The lapse rate of temperature determines the stability of the atmosphere. When the atmosphere is very stable the plumes spread out sideways and vertically very slowly. When the atmosphere is very unstable, the plume spreads out or disperses rapidly.

When the temperature decreases upward at $1^{\circ}C/$ 100 metre , the atmosphere has neutral stability and the plume spreads out like a cone. This particular lapse rate of temperature is called the "dry adiabatic" lapse rate (Table 4-1)

If the temperature decreases with height at a much slower rate than the dry adiabatic rate or if the temperature stays the same with height or if it increases with height, the atmosphere is stable and the plume does not spread out vertically although it may "fan" out in the horizontal. (Topic 4-2, Table 4-1, and Figure 4-2).

If the temperature decreases with height at a greater rate than the dry adiabatic rate, the plume will "loop" upward and downward.

Temperature Change with Height

Change with Height		Lapse Rate	Stability Type
(a)	Decreases at $1^{\circ}C$ per 100 metre	Dry Adiabatic	Neutral
(b)	Decreases faster than $1^{\circ}C$/100 metre	Superadiabatic	Unstable
(c)	Decreases slower than $1^{\circ}C$/100 metre	Subadiabatic	Slightly stable
(d)	No change with height	Isothermal	Stable
(e)	Increases with height	Inversion	Very stable

The types of temperature inversions important in air pollution are the nocturnal or radiation inversion and the subsidence inversion.

The nocturnal inversion forms at night when the ground cools off by radiating its heat outward to space. How deep and strong this inversion is depends upon the wind speed and the rate of cooling of the surface.

The wind must be light (less than 8 km/h) for an inversion to form. Strong winds will mix the air and maintain a temperature decrease with height. A lack of any wind will cause the inversion to be very shallow but very pronounced, since the exchange of heat between the air and the ground will be very slow.

4-4

The nocturnal inversion will not form or will
be weak if the night-time sky is cloudy. The clouds
will absorb the radiation and re-radiate it back to
earth, keeping the air warm in the lower levels.

If the air is moist, a fog will form with the
nocturnal inversion. It will not form with strong
winds and if there is no wind, only dew or waist-high
fog will form.

The depth of a radiation inversion grows as the
night proceeds. It may reach 500 to 700 metre in
depth. Thus, depending on circumstances, its top may
or may not be higher than the height of a smoke plume.

In the morning, a radiation inversion is broken
up by the heat of the sun which warms the ground. The
heat is convected upward higher and higher into the
air until it reaches the top of the inversion. During
the process the inversion layer is elevated and does
not extend to the ground.

The morning inversion breakup will change a
fanning plume into a fumigation situation when the
convective currents reach the height of the plume.
The plume will be spread downward rapidly during a
period of about half an hour during fumigation.

A subsidence inversion is an elevated inversion,
the base of which is generally between 1 200 to 1 800
metre above the ground. It is formed when a layer of
air slowly sinks and warms to a temperature higher
than the air below.

Precipitation is also a cogent factor, reducing gases, wind blown dust and other suspended particulates from the atmosphere by the "scouring" action of rain and snow. Unfortunately, precipitation is undependable so far as frequency and amount are concerned. The proximity of the lakes to Ontario has a bearing on the amount of rainfall in this region. Winds off the lakes occur frequently in both summer and winter, influencing the frequency of rain and snow fall.

Cloud cover is a factor in air pollution levels, tending to increase stability in the lower layers of the atmosphere. Clouds reflect short wave solar radiation back into space at the same time absorbing long wave terrestrial radiation, modifying ground level temperatures. The lower and denser the cloud layer, the more moderate are temperature changes beneath it, with less air movement and cleaning effect. Usually only stratus clouds are associated with stable atmospheric conditions. A high percentage of cloudiness over a period of time allows a persistence of stratus conditions. Conversely, cloudless days produce thermal turbulence and aid large-scale diffusion of pollutants. The periods of greatest instability in this area occur during the summer months which have the least cloudiness. Cloudiness increases sharply in November, reaching a peak in January.

Fog is a manifestation of a number of factors. The atmosphere is made up of air masses of various extent which differ considerably in water vapour content and temperature. Some of the water vapour may be visible to the eye as cloud, but there is usually a vary large amount which is invisible, which we term "relative humidity". Generally speaking, the amount of water vapour which a

mass of air can hold depends on its temperature. It
is possible in several ways for a particular air mass
to be cooled to a point where it can no longer hold
all its water vapour in an invisible state, and some
of the vapour is condensed on the minute particles
always present in the atmosphere, and it becomes visi-
ble. It may form a cloud above the surface of the
earth, or it may appear at ground level as a mist or
fog, or it may only show as drops of water on different
surfaces. The temperature at about which this conden-
sation takes place is called the "dewpoint".

As an example, a mass of comparatively dry air
at a temperature of $16^{o}C$ has at a particular moment a
relative humidity of 50%, but if we drop the tempera-
ture to around $4^{o}C$, the air mass would become very
damp air with a relatively high humidity of about 100%,
and if we drop the temperature still lower some of the
water vapour would condense and we would see mist falling.

All the clouds which we see in the sky and all
the mist, or fog, which occurs on the earth surface, is
formed by this cooling process, always excepting, of
course, the man-made mists and clouds of smoke and dust.

On any clear calm night the earth will lose heat
by radiation at its surface and the air in contact with
it becomes cooled. If the cooling is sufficient to drop
the temperature of the air below its dew point, fog may
be formed; this is known as radiation fog. Fog is also
formed when a comparatively warm and moist air-current
spreads across frozen, or snow covered, ground. Cooling
takes place in the air in contact with the cold surfaces
and fog is formed.

Smog is a combination of smoke and fog. We
mentioned earlier that fog can be caused by water
vapour condensing on minute particles always present
in the atmosphere. If a smoke haze of combustion
aerosols is present in the atmosphere and the tempe-
rature falls below its dew point, the water vapour
condenses on the aerosols forming smog.

The worst development occurs when conditions
favour the development of smog when a temperature
inversion exists. In these conditions the smog gathers
on the surface of the earth, considerably reducing
visibility, and rendering breathing difficult. Such
were the conditions which gave rise to the terrible
smogs in London, England.

Photochemical Smog

The Los Angeles type "smog" is not a true smog,
since it does not contain smoke or fog. In Los Ange-
les, where gas and oil, rather than coal, are utilized,
the smog is light in colour, consisting of solid and
liquid aerosols in a fine state of subdivision, and
numerous organic and inorganic gases. It also differs
from true smog in that it does not occur at night; it
results in intense eye irritation; and it causes charac-
teristic damage to plants.

In this type of smog it has been found that there
is a considerable increase in the concentrations of
ozone and oxidant material in the atmosphere and the
ozone is only found in daylight hours. All known facts
indicate the photochemical formation of ozone or oxidant
from impurities by the action of sunlight. The theory
is that nitrogen dioxide absorbs ultraviolet light

and forms atomic oxygen and nitric oxide. Reaction
of the products with molecular oxygen leads to the
formation of ozone and the regeneration of nitrogen
dioxide. The nitrogen dioxide is, therefore, available
for repetition of the process, unless converted to
nitric acid or used up in organic substitution reactions.
Even low concentrations of nitrogen dioxide could pro-
duce relatively large amounts of atomic oxygen to form
ozone or to react with organic pollutants to yield com-
pounds which could cause eye irritation, crop damage,
and reduced visibility.

In addition to the photochemical reaction between
nitrogen dioxide and oxygen, photochemical side reactions
take place between nitric oxide and hydrocarbons, par-
ticularly those in the unsaturated or olefin group, in
which lachrymators (tear-causing compounds) are produced.
This in turn produces more nitrogen dioxide and so more
ozone.

The greatest source of hydrocarbons and oxides
of nitrogen in Los Angeles (1 motor vehicle to every 2
inhabitants) is the automobile. Some hydrocarbons
evaporate to the atmosphere from storage and automobile
gasoline tanks; some escape during combustion as crank-
case "blow-by" emissions; but the bulk of the emissions
are through the exhaust pipe.

Weather Maps

A weather map will depict some or all of the
following (Figure 4-1):
     1. Lines of constant atmospheric
       pressure - "isobars"
     2. Low pressure areas - "lows"
       or "cyclones"

3. High pressure areas - "highs"
   or "anticyclones"
4. Fronts
   a. Cold
   b. Warm
   c. Stationary

Fronts separate masses of cold and warm air.
The warm air slants above the cold air with height.
If the cold air is advancing, it is a cold front.

Generally, there is a high-pressure area shown
in the warm- and in the cold-air masses. Also, the
fronts are generally shown extending out of low-
pressure areas; frequently, a low-pressure area has
both a cold and a warm air front attached to it.

From day to day, generally, the fronts and
pressure areas will move from west to east. The cold
fronts may move southeast and the warm fronts northeast.

The highs and lows have the following
distinguishing characteristics:
1. High-pressure area
   a. Winds flow outward from a
      high in a clockwise
      direction
   b. Air sinks creating a
      subsidence inversion
   c. Low relative humidity, few
      clouds, little
      precipitation, sunny skies
   d. Low wind speeds, variable
      wind direction
   e. Nocturnal inversions likely
   f. System covers a large area
   g. System moves slowly and may
      remain stationary for
      several days.

4-10

FIGURE 4 -I SURFACE SYNOPTIC WEATHER MAP

2. Low-pressure area
   a. Winds flow inward toward a
      low in a counterclockwise
      direction
   b. Air rises giving good
      dispersion
   c. High relative humidity,
      cloudy, precipitation
      likely
   d. High winds likely
   e. Inversion development
      unlikely
   f. System covers small area
   g. System moves rapidly

Useful Information that can be Obtained from the Daily Weather Map

The passage of fronts or low-pressure areas generally brings precipitation and strong winds. The precipitation will remove most of the particles from the air and improve the visibility. The strong winds will also clean out the air.

After a cold front passes the skies will generally become cloudless. Radiation inversions will form at nights causing fanning plumes in the mornings. The colder weather will produce denser and longer water plumes.

Near the centre of the high-pressure area the wind speeds will be low, the air will be hazy, and visibility will be poor. If the high remains stationary for several days, smog will increase, especially in the fall or summer.

The precipitation preceding a warm front is mostly of a steady type. That accompanying or preceding a cold front is of a showery type.

Wind direction generally is nearly parallel to
the isobars, the lines of constant atmospheric pressure.
If one stands with his back to the wind, the lower
pressure will be on his left and the higher pressure
will be on his right. (In the Southern Hemisphere
this relationship is reversed.)

The weather along a stationary front could be
rain, fog or snow, depending on the season.

Upper level winds (1 500 to 10 000 m) probably
will not be in the same direction as the surface winds
shown on the map. Upper level winds blowing over
oceans, the Gulf of Mexico, or the Great Lakes may
bring cloudiness inland. This will reduce the
illumination and change the background for plume reading.

Ministry Weather Maps

The Air Quality and Meteorology Section of the
Air Resources Branch issues each working day surface
weather maps for the Province of Ontario. These maps
are distributed for use by Ministry staff for the
determination of wind conditions which may affect the
air quality within Ontario. Information presented upon
the maps may, however, be interpreted for other usage.

Data plotted on the weather map is received from
the indicated stations by teletype using the hourly
aviation weather format. A sample message and the
resultant station plot is shown in Figure 4 -2. In
general, each station contains the following information:

1. Cloud cover
2. Wind speed and direction
3. Temperature
4. Present weather
5. Visibility restrictions due
   to fog or haze, if present

4 -13

Definition of the symbols used are defined in Tables
4-1, 2 and 3.

In addition to station data, larger scale weather
systems which affect the coverage area are plotted. These
include frontal systems, pressure centres, and general air
flow patterns. The symbols used to represent these elements
are shown in Table 4 -4.

Weather patterns may be interpreted using the
following rules of thumb:

1. The protuberances on the frontal symbols indicate
    the direction that the front is moving.

2. Surface air flow patterns may not indicate the
    direction in which weather elements are moving.

3. Weather patterns generally move from SW to NE,
    W to E, and NW to SE.

4. The passage of a frontal system generally changes
    the character of the weather.

5. Warm fronts are generally characterized by rising
    temperatures, southerly component winds, low
    clouds and/or fog, and persistent precipitation.

6. Cold fronts are generally characterized by
    falling temperatures, westerly or northerly
    component winds, and showery forms of preci-
    pitation from convective clouds.

7. Stationary fronts are generally characterized
    by persistent conditions of wind, precipitation,
    and cloud cover (generally low). Stationary
    fronts may vacillate over an area bringing
    significant changes in the weather as the
    frontal line passes the station.

FIGURE 4-2

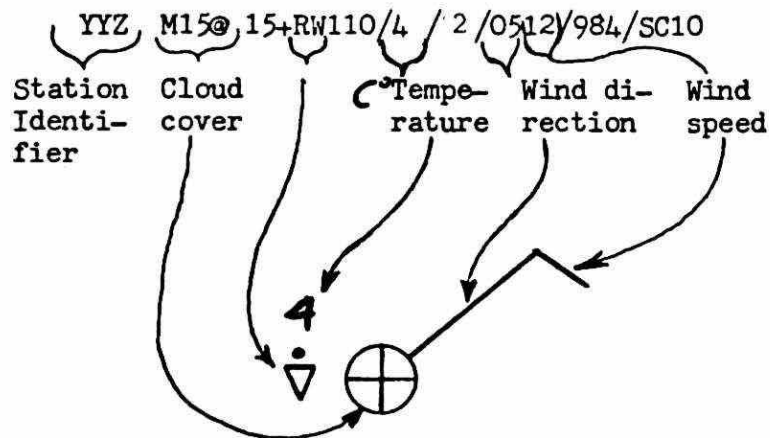## SAMPLE WEATHER MESSAGE AND PLOTTED STATION

YYZ, M15@,15+RW110/4 / 2 /0512/984/SC10

| Station Identifier | Cloud cover | | Temperature | Wind direction | Wind speed |

TABLE 4-1

CLOUD COVER

O   Clear

⊕   Scattered

⊕   Broken

⊕   Overcast

⊗   Obscured

TABLE 4-2

WIND SPEED AND DIRECTION

◎   Calm

3 km/h wind

8 km/h wind

16 km/h wind

24 km/h wind with gusts to 40 km/h

80 km/h wind

Each full barb represents 16 km/h

Each half barb represents 8 km/h

Wind direction - arrow points in direction wind is coming from.

Table 4 -3

PRESENT WEATHER TYPE

∞	Haze	= =	Fog patches
⌐	Smoke		
½ ≣	Fog and Visibility (Miles)	⤊	Blowing snow
,	Very light drizzle	,,	Light drizzle
•	Very light rain	┿	Drifting snow
• •	Light rain		
••	Moderate rain	⇸	Heavy drifting snow
••	Heavy rain		
✳	Very light snow	⚡	Snow pellets
✳ ✳	Light snow	⚤	Snow grains
✳✳	Moderate snow	◁	Lightning
✳✳✳	Heavy snow	V	Squalls
		↔	Ice crystals
∇̇	Rain showers	∇̓	Heavy rain showers
✳∇	Snow showers	✳∇	Heavy snow showers
ℝ .	Thundershowers	ß	Heavy Thunderstorm
∿	Freezing rain		
∿	Freezing drizzle		
△	Hail		
◬	Ice pellets (Sleet)		

Table 4-4

PLOTTED WEATHER SYSTEM SYMBOLS

▼▼▼ (cold front symbol)	Cold Front
●●● (warm front symbol)	Warm Front
▼●▼● (stationary front symbol)	Stationary Front
L	Low Pressure Front
H	High Pressure Center
⟶ (air flow arrow)	Air Flow Pattern
⟶⟶⟶ (trough symbol)	Trough

OBJECTIVES:

The trainee will be able to:

1. Define:

    a. Dust fall
    b. Aerosols
    c. Gases

2. Recall the sampling methods used
    to measure:

        Aerosols

AIR POLLUTION MEASUREMENT

GENERAL

Air pollution may be defined as a mixture of one or more contaminants of solids, liquids, or gases discharged into the air by nature and/or by man in such quantities and of such duration which may be, or may tend to be, injurious to human, animal, or plant life or property, or which may interfere with the comforts of life itself.

From a physical standpoint, all pollution added to the air falls into three classes:

1. Dustfall

2. Aerosols

3. Gases

Dustfall

This is the term to describe all particles of a certain size which do not stay suspended in the air, and tend to be deposited very near their origin. From the combustion of coal, these large particles could be fly-ash (mineral matter from completely burned coal), or grit (unburned or partly burned coal). From non-combustion processes, such as grinding, or road and building construction operations, mineral matter is disturbed and deposited near this type of activity. Generally speaking particles of sizes larger than 100 μm are deposited near the source of emission.

Aerosols

Stokes' Law states that the velocity of free fall of small particles in still air is proportional to the square of the diameter. With a density of 1,

the free fall for particles

50 μm diameter is 7.5 cm/sec = 4.5 m/min

20 μm diameter is 1.38 cm/sec = 0.83 m/min

10 μm diameter is 0.3 cm/sec = 0.18 m/min

For a particle 1 μm in size, the free fall is 13 cm per hour. If the density of the particle is 2, the free fall of the particle is twice the rate given above for the various particle sizes.

It should be noted that aerosols may be solid or liquid. Liquid fumes (e.g. SO_3) are generally in the size range 0.1 to 1 μm, tobacco smoke and most smoke particles are less than 0.5 μm in diameter.

Gases

The behaviour of gases in the air depends on their density and the density is indirectly proportional to temperature. When gases such as SO_2 are emitted at high temperatures, the plume rise may be considerable before the gases cool to the ambient air temperature, thereafter they are subject to large scale atmospheric diffusion. The dilution and dispersion of gases and aerosols in the atmosphere are similar; the main difference is that on impaction on a solid surface, aerosols will be removed from the air where gases will not.

The Ministry of the Environment utilizes the latest designed instruments available in their air quality monitoring program, the method of sampling varying with the classes of air pollution we have just considered.

SAMPLING METHODS

Dustfall

In Ontario, the method used for collection is that
laid down by the Air Pollution Control Association
Committee. The collector consists of a plastic jar
15.2 cm diameter and 38 cm long, a cross-sectional area
of 181 cm^2. The collectors are exposed for approximately
30 days. During this period they collect rain, snow
and dust. In the summer high evaporation may cause the
collectors to become dry, while in winter they become
frozen. Dustfall measurements are reported in
g/m^2/30 days.

Since the type of activity in the area will determine
the amount collected, the type of activity within the
area must be described. Such description would note
whether the sample came from an industrial, commercial
or residential area, and location of the jar. This type
of measurement is useful in locating gross pollution
sources, and for indicating long term trends. An analysis
would contain: water soluble solids; metal analysis, and
microscopic examination of collected particulates.

The interpretation of the results will give a mean
figure and is a useful measurement of the monthly, or
yearly dustfall.

Aerosols

The two most common methods used in Ontario for
measuring the aerosols suspended in the air are: the high
volume sampler and the low volume sampler.

1.   High-volume Sampler

The original high-volume sampler consisted of
the motor and blower of a cylinder-type vacuum
cleaner, suitably enclosed and fitted with a holder

for flat filter paper instead of a dust bag. Present versions are more refined, but little different in concept. Current samplers are generally exposed inside a case which places the filter surface horizontal, facing upward, under a roof which keeps out rain and snow, and generally prevents collection of particles larger than about 100 micrometre.

This air sampler draws a large amount of air, 1.13 m^3/min. for 24 hours through a fibreglass filter paper measuring 20 x 25 cm. This paper is weighted before and after sampling, the difference in weight being the weight of aerosols collected, in approximately 1 631 cubic metre of air during a 24 h period. The loading is reported in microgramme per cubic metre of air. The criterion used for this type of sampling is 120 microgramme per cubic metre per 24 hours. Readings above this figure indicate that some form of control is advisable. Detailed analysis can be carried out from the filter paper - chlorides, carcinogens and radioactive fallout being measured. Trace amounts of metals, vanadium, silver, zinc, beryllium etc., can also be found by analysis.

2.   Low-Volume (R.A.C.) Sampler

This sampler operates continuously, drawing outside air through a roll of #3 Whatman paper at a flow rate of 6.5 litre/min. Air is drawn through the paper for a selected time, usually one or two hours and a new portion of tape is then automatically moved into position and sampling is resumed. Aerosols deposited on the paper form a "spot" stain which can be evaluated by measuring the reduction of light transmitted through the soiled paper as compared with clean paper. The unit of measurement is the Co-efficient of Haze - Coh/1,000 ft. (304.8 m)

Because of the low flow rate the sample collected on the paper consists of fine aerosols that are smaller than 10 μm and can be carried into the lungs.

The Ontario criteria is 1.0 Coh for 24 h.

3. Gases

Gases occur in the atmosphere in very small
concentrations and require more refined sampling
methods.

SO_2 is the commonest gaseous pollutant, occur-
ring as an end-product in the combustion of all
fuels. Field measurements of sulphation are made
by exposing porcelain or glass cylinders covered
with tapestry cloth and coated with a thin paste of
PbO_2 (lead dioxide). They are housed in special
containers and located in the area under investigation
for a month at a time. The reactive sulphur in the
air combines with the lead dioxide to form $PbSO_4$
(lead sulphate). Reagent and product are both in-
soluble, but the rate of reaction is affected by
moisture, wind speed and particulates. The special
container, therefore, is necessary to protect the
reagent from rain and snow. The container has louvred
sides to allow free passage of air through the
container.

By this method, the amount of reactive sulphur
compounds in the air can be approximately estimated
in the laboratory, and with several of these units
around a source of SO_2, qualitative results can be
achieved to indicate the increase and decrease of
emissions, the area most heavily polluted, and in
some cases the chances of vegetation damage.

Where more precise information is required of
the hourly concentrations and their variations, a
continuous sulphur dioxide analyser is available for
continuous readings, but this instrument requires
attention by skilled instrument technicians.

Fluorides may also be measured in the field
by a technique similar to the sulphation candle.
#4 Whatman paper dipped in a slurry of lime or
calcium formate is wrapped around the porcelain
cylinder and exposed in a screen for a period of
a month in the area under survey. Chemical analysis
indicates the approximate level of fluoride contamina-
tion at the different sampling points. Gaseous fluoride
measurements are also taken by specific gaseous
fluoride analyses.

Hydrogen sulphide can be measured by a volume
instrument similar in operation to the continuous
sulphur dioxide analyser.

Other gases can be measured using continuous
recording instruments, such as ozone, nitric oxide,
nitrogen dioxide and total nitrogen oxide, SO_2, CO,
and hydrocarbon meters. These are specialized units
and require skilled attention.

The fluoride candle is useful as a semi-quantita-
tive method for indicating the sources of fluoride (F)
and if there is a problem in the area, continuous
fluoride analyzers are required for accurate information
on gaseous fluoride levels.

USE OF VEGETATION IN ASSESSING AIR QUALITY

Vegetation monitoring alone or in conjunction with air
quality measurements has proven to be a valuable tool in
assessing air quality. While air quality instruments measure
concentrations of particular contaminants in the air and
provide their frequency of occurrence and duration periods,
they act primarily as a barometer with respect to effects.
However, vegetation monitoring does provide the actual
effects resulting from adverse air quality levels.

An experienced phytotoxicologist conducting a vegetation assessment survey in an area surrounding a particular source can tell whether a pollutant of phytotoxic concentrations has been emitted: can diagnose what the pollutant is, for example, SO_2, HF, Cl_2, NH_3, C_2H_4; and can judge whether the pollutant came from the direction of the source. In doing this, the phytotoxicologist must be able to identify various kinds of plant species, know the symptoms of air pollutant injuries, be able to differentiate injuries caused by diseases, insects and weather; and collect samples for laboratory analysis indicating whether the samples should be processed for pathology, histopathology or chemical analysis. If for chemical analysis, he must be able to indicate which contaminants the samples should be analyzed for and be able to interpret the results in context with other observations.

Observations made in the field are most important in assessing the effects of air quality. The laboratory examinations of collected samples supplement and confirm the field observations. Plant species vary considerably in their sensitivity to air pollutants, and the occurrence of injury, the species affected, and the degree and extent of damage can only be determined from a thorough field assessment investigation.

However, there are a number of other factors which must be taken into consideration. It has been determined from both field observations and controlled environment studies that in addition to the concentration and duration of a contaminant (called dose), other factors must be acting in concert for damage to occur to vegetation. Some of these factors are the type of plant species present, the physiological and biological growth stage of the plant, and climatic variables such as air temperature, wind, relative humidity, soil moisture and light intensity. If all

or most of these factors are not conductive to plant in-
jury, plants will resist injury even at concentrations
four to five times higher than those levels which are
usually found to be responsible for injury. And,
conversely, if these factors are especially conductive
to injury, sensitive plant species can be injured by
pollutant concentrations much lower than those usually
required to cause injury to native vegetation. There
are also differences between acute and chronic effects to
consider, in which acute injury is usually caused by
short-term high concentrations of a particular air pollu-
tant, and chronic injury is caused by long-term exposure
to variable concentrations of the pollutant including
pollutant-free periods.

Vegetation is also used to assess the effects of
photochemical oxidants. Phytotoxicology surveys conducted
annually have indicated that white bean, tobacco and tomato
crops in southern Ontario suffer annually as a result of
photochemical air pollution. Ozone and peroxyacetyl
nitrate are the main phytotoxic oxidants formed in the
atmosphere in the presence of sunlight and the primary
pollutants, hydrocarbons and nitrogen oxides. These
oxidants, O_3 and PAN, are not emitted directly by any
source thus making control difficult. The main source of
the precursor contaminants are automobiles and the exhaust
emitted many miles away in the United States and can be
responsible for oxidant injury to crops in Southwestern
Ontario. For example, white bean crops in an area of
about one million acres suffer to some degree every year
from the effects of ozone. Means are currently being
examined to protect crops from ozone injury by chemical
sprays or by the use of resistant plant varieties.

In addition to examining native vegetation, indicator
plots are used to assess air quality. These plots con-
sisting of plant species, which are raised in clean-air
greenhouse and known to be sensitive to different air

pollutants, are established at various distances and directions from a particular source. The indicator plants detect the presence of atmospheric pollutants as ozone, PAN, sulphur dioxide and fluorides. A new moss bag technique is being used to assess heavy metal contamination. The advantages of biological monitors to assess air quality are:

1. the monitors are inexpensive,
2. numerous plots can be established surrounding a source.
3. the plots are easy to maintain.
4. they can readily delineate the degree and extent of contaminant effects surrounding a source.

SUBJECT:

INDUSTRIAL ABATEMENT -
AIR MANAGEMENT

TOPIC: 6

THE ENVIRONMENTAL OFFICER'S
DUTIES AND RESPONSIBILITIES

OBJECTIVES:

The trainee will be able to:

1. List six items related to conduct
    and practices which must be given
    close attention in order to avoid
    any possibility of misunderstanding
    on the part of the public;

2. List the five parts of an inventory
    inspection or survey breakdown;

3. List the headings under which a
    complex survey report would be
    written;

4. List nine items of information which
    should be obtained when investigat-
    ing a complaint;

5. Describe the three characteristics
    of a plume;

6. Name and sketch the various shapes
    of a plume;

7. Define: smoke, fumes, dust, mist,
    gas, vapour.

THE ENVIRONMENTAL OFFICER'S DUTIES
AND RESPONSIBILITIES

GENERAL

The officer must be able to comprehend the law he enforces and relate it to the corresponding practical situation encountered in the field. Perhaps the most important single attribute that the officer should possess is the ability to make logical and reasonable judgments. Emotional stability is also an important quality. The officer must remain consistent and reliable without being readily influenced. He must be free of prejudices and biases which influence his judgment. He must be capable of analyzing situations for the objective facts and be able to enforce the law equally and firmly.

The ability of the officer to express himself completely and accurately, orally and in writing, is also important since his findings are always being reported for proper action. Oral expression ability is particularly important when an officer testifies in Court or explains a law or correct operating procedure to a plant operator, an owner or management.

Approach and appearance are also important, since the kind of appearance the officer makes before the public influences compliance directly by his ability to obtain respect for, and confidence in, his position and the Ministry. The officer's ability to perform his assigned duties effectively, given a technical proficiency, will stand or fall on the manner in which he conducts himself with the public. Since the officer is in the field most of the time, he is constantly dealing with people whose attitudes to him may be various, but whatever the attitude the officer must be polite and courteous, yet firm when required.

Ethics deal with principles of honesty, of right action. For the environmental officer ethical conduct and practices should be largely a matter of common sense, but there are several items which must be given close attention, particularly in a governmental agency, in order to avoid any possibility of misunderstanding on the part of the public:

1. Officers do not take any action or make any statement which interferes with any official act or decision of the Ministry.
2. Information acquired in any plant should never be disclosed to a competitor.
3. The law must be applied uniformly to all.
4. No firms or individuals can be recommended for air pollution control projects.
5. Reports must not in any way be falsified.
6. No gratuities should be accepted.

MAKING AN INSPECTION

The classification of work and sources of air pollution break down so extensively that it is difficult to generalize on methods and principles, or to illustrate typical instances, but the steps taken in making an air pollution field inspection follow a pattern. An original inventory survey is chosen here since it is usually the most thorough inspection conducted. The violation inspection, or other types of inspection differ according to the type of air pollution problems encountered.

The inspection breaks down into five parts:

1. Observation of plant exterior
2. Interviewing plant management
3. The physical inspection of equipment
4. Concluding the inspection
5. Presentation of the report

Observation of the Exterior

The outside of the plant is the first thing that the officer observes. The general layout, relative size and location of stacks, vents, and incinerators are particularly noted, by sketch or photograph. The officer estimates the possible contaminants that could be emitted into the atmosphere by such a plant. He tours the periphery of the plant, unless it is so small that it can be properly observed without the tour, and takes notes to make certain that all observations of visible air contaminant emissions are recorded. Particular attention is paid to points of observation, location of emission, time, colour, opacity of contaminant and accuracy of source description.

Interviewing Plant Management

The officer enters the plant, identifies himself and attempts to contact the top authority before conducting any business with any other person within the plant. The officer makes an effort to see the head of each plant personally, and in the event that this person is out, the next in authority and so on. This rule applies every time a plant is entered, unless the head of the plant designates a certain person to be contacted on future visits. This is a procedure which the dignity of the situation as well as common courtesy demands.

Before the plant is inspected, the officer informs management of his planned inspection of the premises. Usually permission to enter is granted without question, but at times it is necessary to explain that the Act gives the officer the right of entry. The officer either reads or shows the plant head the relative section of the Act. If permission is then refused, the officer does not enter forcibly but asks for a direct verbal refusal of entry and then informs the party concerned that by his refusal he is

not complying with the requirements of the Act. The
officer then reports at once by telephone to headquarters
for further instructions. Refusal of entry is rare,
however, as most plants are prepared to co-operate. Where
a routine inspection is planned, the possibility of refusal
can be easily avoided by making an appointment in advance
by telephone.

The officer then interviews the representative
of plant management contacted. The interview serves to
inform the management of the purpose of the inspection;
imparts all information the plant manager may require
regarding the air management programme; elicits any
information the officer may require about the operation
of the plant; and organizes the inspection.

The officer approaches any individual in the
plant at his own level of speech and understanding. It is
not done to use extremely colloquial English with an
executive, but on the other hand, the officer should not
assume a superior attitude and use complicated words with
a person whose vocabulary is limited. The officer uses
as clear expressions as will adequately describe whatever
idea he is trying to implant. An interested and sincere,
but not unfriendly attitude, creates the most desirable
atmosphere for accomplishing the officer's purpose.

After the plant manager is informed of the visit,
the officer then gathers preliminary data regarding the
ownership of the plant, and the basic processes conducted
by the plant. If the plant is exceptionally large or the
processes employed are complex, the officer plans the
inspection with the manager or whoever is subsequently
detailed to accompany him. The company escort thus assists
the officer in making a complete inspection.

In planning the inspection, the basic manufacturing processes are usually discussed. This provides an opportunity for the officer to ask questions about unfamiliar processes beforehand. This is often quite helpful, since the working area of the plant may be too noisy for normal conversation. The officer after learning of the steps taken in the process, can formulate a department-by-department inspection plan. He generally follows the flow of materials, the actual steps through which the manufacturing process is conducted. As this is discussed, the officer collects operating data which he can verify when he inspects the equipment. A friendly discussion of this nature at the beginning of the inspections saves much time.

The Physical Inspection

The plant to be inspected will comprise one of two distinct types of situations:

1. A plant consisting of individual pieces of equipment units, such as foundry, even though individual operations may be conveyorized.
2. Plants constructed on the basis of process units, i.e. equipment unit interconnected by sealed or ducted flow systems.

In a plant that is relatively simple, it is only necessary to list equipment units. In a more complicated plant a generalized box-flow diagram may be required. Regardless of the type of plant, the officer should always provide the information or diagrams necessary to describe the plant to one who has not seen it.

The officer then inspects each equipment unit individually and acquires information from his observations and enquiry. In collecting inventory data it is essential

to write down the data at the time it is given to avoid errors. The officer should:

1. Identify the equipment units by function, commercial name and plant location.
2. Analyse the physical operation of the equipment, from influent to effluent, determine degree of operation and use, and note capacity and general operation or efficiency.
3. Check and evaluate all pertinent maintenance and operational practices.

Much of the data can be observed directly at first hand, especially if the equipment unit is in full operation. Other data can only be elicited by asking developmental questions. If the latter approach is required, it is often best for the officer to be genuinely interested in the process, and to be curious about its operation. In dealing with statements, the officer may repeat them to ensure their accuracy. This can always be done by stressing the fact that an accurate record of plant information protects management against the use of incorrect information.

It should be noted that the officer does not directly order or instruct the operator in proper operation and maintenance procedures. The officer prescribes results rather than methods of obtaining results. He can discuss effective control practices as he knows them, but he is always careful to explain that the methods employed are up to management.

CONCLUDING THE INSPECTION

In concluding the inspection, it does no harm for the officer to compliment the plant operator on a well operated and clean plant. However, the operator is not told that he

"does not violate" the Act or Regulations when what is meant is that he is not violating it at the particular moment under consideration.

At this point, the officer may desire to review the results of the inspection with the plant operator. If the the plant manager needs approval application forms for proposed new equipment, the officer explains the procedure for submitting the applications and may supply the necessary application forms. If interest has been shown in the overall air pollution problem the officer may leave appropriate information publications.

The officer then takes his leave without unnecessary delay. The plant operator or manager has taken time from his usual duties to be with the officer and his time represents money. The leave is taken on a friendly note.

WRITING THE REPORT

After the officer completes the inspection, he completes his report. If reports are to be short, they should be written as soon as the officer reaches his vehicle. At instances, when inspections are highly technical or are involved, and data at headquarters are required, the officer may complete his report at headquarters.

The officer must be able to select essential and relevant details and to describe them accurately and coherently. This is important since the officer may have gathered a great deal of information, of which only a portion relates to the air pollution problems which may be encountered. The officer attempts, however, to be complete and accurate.

Upon arrival in the vicinity, the officer first observes the source to determine if a violation is involved. If a violation is observed, the officer investigates, writes and serves a notice, if warranted. Then he visits the complainant. However, if no violation is immediately apparent, the officer contacts the complainant first. This is most often the procedure followed.

The officer makes every effort possible to avoid obvious identification of the complainant. He is particularly careful not to park an official vehicle too close to the complainant's residence should the complainant and the source be near each other. The officer considers the identities of all complainants to be confidential and never, under any circumstances, discloses them to anyone who is not an employee of the Ministry.

The officer then attempts to contact the complainant. If he is not at home, he leaves his calling card, and tries to contact him again at some other time. If he is at home, the officer identifies himself by name and agency in a friendly manner.

The ability to listen carefully is one of the skills the officer develops to get the facts. The officer is friendly, but dispassionate. He generally employs "non-directive" interview technique in that he allows the complainant to get the matter off his chest so that the facts of the situation can be calmly discussed. The officer also appreciates the fact that a person who is angry may honestly be motivated by a serious or chronic air pollution condition. In permitting the complainant to speak his mind, it is well for the officer not to interrupt. It is particularly effective, however, when facts appear, for the officer to repeat them aloud for verification, and then jot them down.

After the complainant has expressed himself, the
officer proceeds on a line of questioning which will
determine the cause of the complaint, and the nature and
source of the air pollution problems cited in the complaint.

The cause of the complaint, it should be noted, may
not always involve air pollution. Although most complaints
are justified, some will concern problems over which the
Ministry has little or no control and in which air pollution
may play a minor roll. These concern backyard feuds, natural
contaminants, or perhaps resentment towards a nearby company.
Although the officer may have no legal powers in such
cases, he thoroughly investigates and attempts to correct all
air pollution problems. If such complaints are unsubstantiated,
the officer establishes the cause of the complaint, and
documents the fact that no violation has occurred by recording
the operational data of the equipment at the alleged source.

In verifying the validity of the complaint, the
officer attempts to recognize contradictory, exaggerated
and biased statements. He may politely challenge terms
used by the complainant to denote frequency or inclusiveness
such as "generally", "sometimes", "never", "all of the time",
"rarely", in order to distinguish first hand knowledge or
experience from speculation and inference. Precise indications
of frequency may be crucial in tracking a source.

In order to obtain the necessary data, the officer
enquires to obtain the following:

1. Name and location of source complained of
2. Frequency of annoyance or occurrence of plume
3. Time of day it was first noticed
4. Duration of each occurrence
5. Names and addresses of persons affected, if any
6. Location and extent of property damage, if any

7. Description and frequency of any illness alleged to have resulted from the air contaminants
8. Description of odours, if any involved
9. Any other information the complainant may have that will relate to the problem to a specific piece of equipment.

While interviewing complainants, the officer does not promise legal action nor does he commit himself or the Ministry to any course of action. He may, however, explain to the complainant the law involved and the evidence that may be required to instigate legal proceedings, if asked.

During the course of the interview, the officer examines the complainant's property for any deposits or effects of air contaminants such as paint or acid stains, dusts, odours, flyash, etc. The pattern of fall-out of contaminants may indicate the direction from which they came. If a malodour is detected at the complainant's property, the wind direction can be determined for purpose of tracing the odour to its source.

From the facts gathered so far, the officer may already have a notion of what it is he should inspect, especially if he has identified contaminants and has observed definite evidence of damage, or detected odours on the complainant's property. In other cases he may know the identity of the contaminant but not the source of origin, and will first have to locate a possible source to inspect. In still other cases the contaminant may be completely unknown. The tracking and identification of contaminants are discussed later.

EFFLUENT FORMATION AND COMPOSITION

An effluent of air contaminants is a colloidal system, i.e. - a suspension of particles in the air or other gaseous medium, or a gaseous mixture released as a plume from a specific source outlet. Contaminant plumes may be either visible or invisible to the naked eye. Visible effluents are those which consist of any one or combination of the following contaminants:

1. A sufficient concentration of a coloured contaminant gas, such as nitrogen dioxide (brown to yellow), bromine (reddish-brown), iodine (Purplish), and chlorine (greenish-yellow). With the exception of these gases, however, virtually all contaminant gases significant in air pollution are colourless.

2. Aerosols, seen by light-scattering, greater than 0.4 μm (400 to 700 nm).

In the case of aerosols, the visual threshold is dependant upon the intensity and the direction of the light source with respect to the observer, and the position and concentration of the effluent. The maximum visibility reduction occurs when the light source is directly opposite the observer and behind the effluent. As the observer changes his angle of position, the visual effect of the light scattering diminishes until, at a change of 180° of position, the visual effect is nil.

Effluents are invisible when the aerosols cannot be seen with the naked eye, or they consist of colourless gases, or the concentrations of visible materials are too low to be detected by the naked eye.
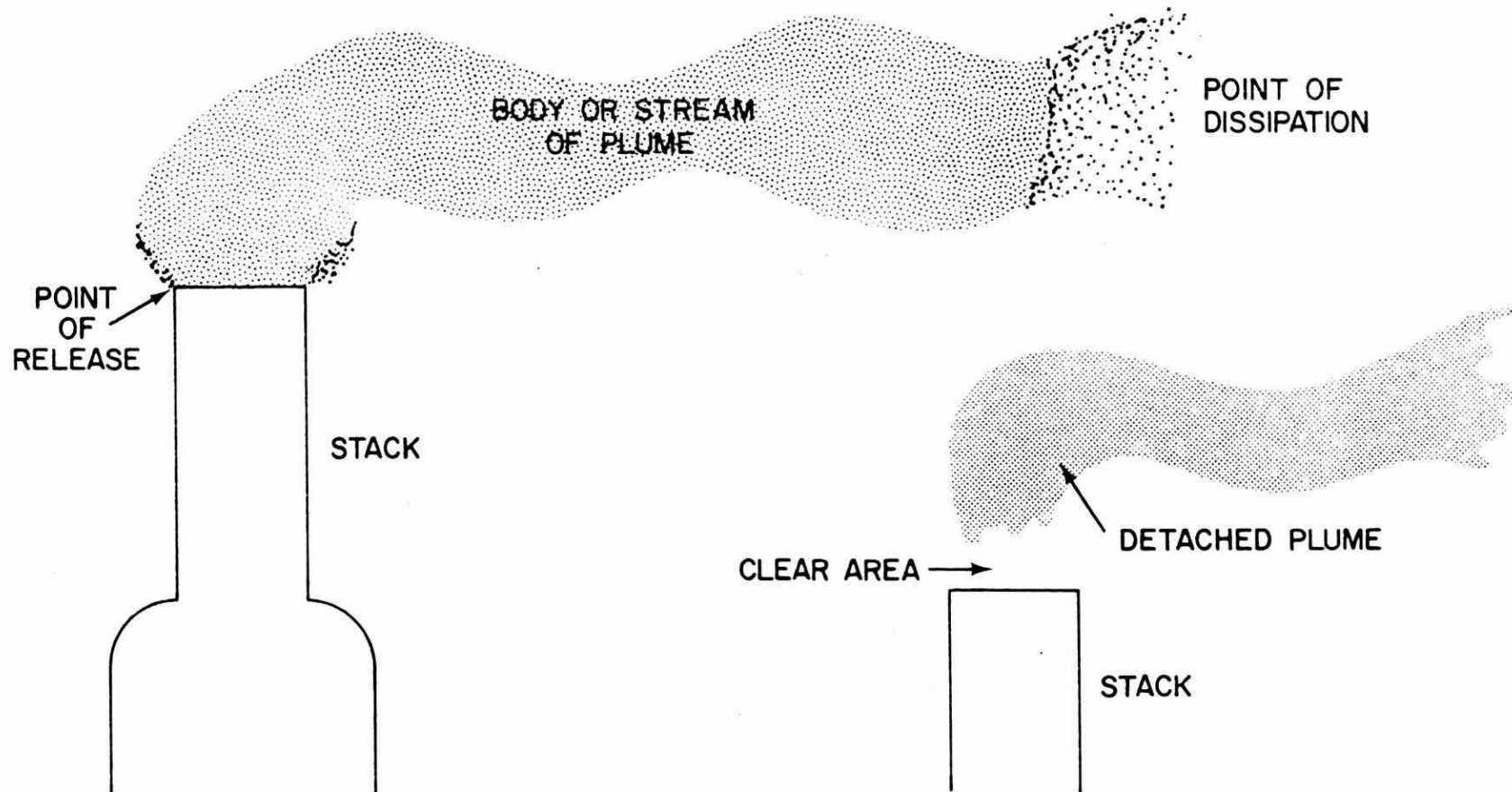
Plume Characteristics and Behavior

The plume or effluent is the flow itself of the contaminant-laden gas stream from a specific outlet such as a stack or vent. The plume (Figure 6-1), particularly when it is distinctly visible, is characterized by:

1. A point of release and formation just at the outlet of the stack or opening of a closed system, or a few feet above the outlet in the case of a "detached" plume.

2. The body or stream, comprising most of the contaminants carried by the momentum of the escaping gases.

3. The point at which the plume or effluent dissipates.

The breakdown of the plume structure is important. The point of discharge of the emission is the point at which the opacities of visible emissions are read or sampled. The stream or body of pollution provides some relative notion of quantity and velocity of the escaping contaminants, as well as other characteristics such as colour and particle size which help identify the plume. The point of dissipation is also important in determining whether or not the plume is a contaminant, water vapour or steam, or some combination of both. Depending on wind velocity, humidity and temperature, water vapour or steam tends to dissipate more rapidly than any contaminants contained in the effluent. The greater the humidity, generally speaking, the longer will be the steam plume.

General atmospheric conditions may also be indicated by the behaviour of the plume (Figure 6-2 and Table 6-1), and may be of significance in assessing the problem. A plume which rises straight up, for example, indicates rapid vertical mixing of contaminants

General structure of continuous and detached plumes, respectively.

Fig. 6-1. STRUCTURE OF A PLUME

TABLE 6-1

PLUME BEHAVIOR AND RELATED WEATHER

Description of Visible Plume	Typical Occurrence	Temperature Profile-Stability	Associated Wind and Turbulence	Dispersion and Ground Contact
Irregular loops and waves with random sinuous movements; dissipates in patches and relatively rapidly with distance.	During daytime with clear or partly cloudy skies and intense solar heating; not favored by layer-type cloudiness, snow cover or strong winds.	1. Looping Adiabatic or super-adiabatic lapse rate-unstable.	Light winds with intense thermal turbulence.	Disperses rapidly with distance; large probability of high concentrations sporadically at ground relatively close to stack.
Roughly cone-shaped with horizontal axis; dissipates farther down-wind than looping plume.	During windy conditions, day or night; layer-type cloudiness favored in day; may also occur briefly in a gust during looping.	2. Coning Lapse rate between dry adiabatic and isothermal-neutral or stable.	Moderate to strong winds; turbulence largely mechanical rather than thermal.	Disperses less rapidly with distance than looping plume; large probability of ground contact some distance downwind; concentration less but persisting longer than that of looping.
Narrow horizontal fan; little or no vertical spreading; if stack is high, resembles a meandering river, widening but not thickening as it moves along; may be seen miles downwind; if effluent is warm, plume rises slowly, then drifts horizontally.	At night and in early morning, any season; usually associated with inversion layer(s); favored by light winds, clear skies and snow cover.	3. Fanning Inverted or isothermal lapse rate-very stable.	Light winds; very little turbulence.	Disperses slowly; concentration aloft high at relatively great distance down-wind; small probability of ground contact, though increase in turbulence can result in ground contact; high ground level concentrations may occur if stack is short or if plume moves to more irregular terrain.

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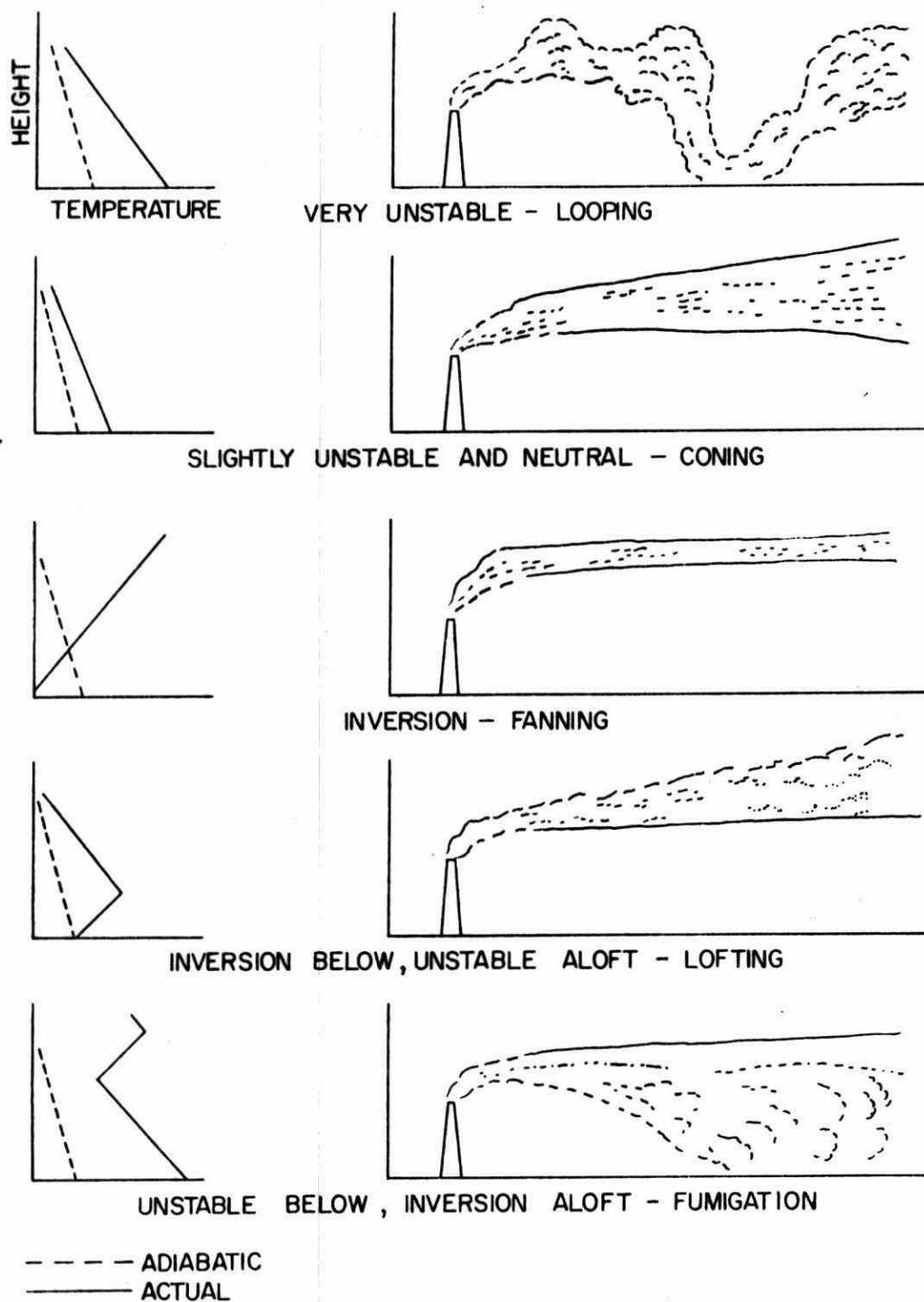| Description of Visible Plume	Typical Occurrence	Temperature Profile-Stability	Associated Wind and Turbulence	Dispersion and Ground Contact
Loops or cone with well defined bottom and poorly defined, diffuse top.	During change from lapse to inversion condition; usually near sunset on fair days; lasts about an hour but may persist through night.	4. Lofting Adiabatic lapse rate at stack top and above; inverted below stack--lower layer stable, upper layer neutral or unstable.	Moderate winds and considerable turbulence aloft; very light winds and little or no turbulence in layer below.	Probability of ground contact small unless inversion layer is shallow and stack is short; concentration high with contact but contact usually prevented by stability of inversion layer; considered best condition for dispersion since pollutants are dispersed in upper air with small probability of ground contact.
Fan or cone with well defined top and ragged or diffuse bottom.	During change from inversion to lapse condition; usually nocturnal inversion is being broken up through warming of ground and surface layers by morning sun; breakup commonly begins near ground and works upward, less rapidly in winter than in summer; may also occur with sea breeze in late morning or early afternoon.	5. Fumigation Adiabatic or super-adiabatic lapse rate at stack top and below; isothermal or inverted lapse rate above--lower layer, unstable or neutral, upper layer stable.	Winds light to moderate aloft, and light below; thermal turbulence in lower layer, little turbulence in upper layer.	Large probability of ground contact in relatively high concentration, especially after plume has stagnated aloft.

TABLE 6-1 (Con't)

FIG. 6-2 EFFECT OF ATMOSPHERIC STABILITY ON PLUME BEHAVIOUR

favourable to the dissipation of the contaminants. Horizontal plumes, however, may cause fumigation of an area down-wind from the source of emission. The direction and extent of diffusion may then be indicated by the type of plume. A plume which disperses both vertically and laterally is known as a coning plume, in that the shape of dispersion is in the form of a cone. A coning plume generally results when wind speeds are in excess of 30 Km per hour. A looping plume occurs in turbulent or gusty atmospheres, and in general, results in good dispersion and only sporadic fumigation. A fanning plume generally results from a steady, and sometimes slow, wind stream, and tends to maximize the area of effective fumigation possible at relatively high contaminant concentrations.

In most cases, a trained observer can distinguish between smoke and fumes by colour, behaviour and dissipation point. Since a fume consists of relatively heavier molten liquid droplets which condense rather rapidly to a solid or mist, the point of dissipation is often closer to the stack outlet than in the case of smoke particles. Also, fume plumes often tend to form hazes sooner than do smoke plumes.

An experienced observer can also distinguish between emissions of smoke resulting from rubbish burning, fuel-oil burning, and even natural gas, when gas-fired boilers are severely out of adjustment, by colour and escape velocity of the body of the plume.

Of course, these generalizations must be supported by a thorough inspection of equipment and processes.

Since all substances become liquid, solids
and gases at certain temperatures, any effluent or
plume will consist of a variety of contaminants in
various states of matter. Smoke, for instance, may
consist chiefly of aerosols - carbon particles and
solid or liquid particles (acids and aldehydes) of
partially burned fuels - but may also consist of
such gases as sulphur dioxide, oxides of nitrogen,
or unburned vapours generated in the gaseous state.

Here again, the identity ascribed to the
effluent is generally made in terms of its out-
standing visual characteristic. For example, even
though sulphur dioxide may be the most significant of
the contaminants emitted from a stack, the effluent
in which it is contained is frequently described as
smoke due to the visible soot, carbon particles and
fly-ash also contained in the plume.

The mere observation of a plume, however,
does not result in its conclusive identification,
the officer will require knowledge of the specific
conditions which cause the contaminant. The tech-
nical distinction between smoke and fumes cannot
be made unless the process by which they are gene-
rated is described. With this is mind we may
define each of the six categories of effluents:
smoke, fumes, dusts, mists, gases, and vapours.

Smoke

Smoke is the visible effluent resulting
from incomplete combustion and consisting mostly
of soot, fly ash and other solid or liquid par-
ticles less than 1 μm in diameter. Depending
upon the composition of the fuel or materials being

burned and the efficiency of combustion, various
volatilized gases and organics such as aldehydes,
various acids, sulphur dioxides, nitrogen oxides,
and ammonia may also be emitted. When complete
combustion occurs, only carbon dioxide, water
vapour and small amounts of ash are emitted. Thus
the generation of smoke depends on the efficiency
of combustion equipment in relation to the fuel or
material being burned.

Smoke will vary in colour, but will be
generally observed as grey, blue, black, brown and
white, sometimes yellow, depending upon the con-
ditions under which certain types of fuels or
materials are burned. The colour of smoke is
generally a fairly good indication of the type of
combustion problem encountered. Smoke which is
grey or black in colour may indicate the material
is being burned with insufficient air or inadequate
mixing of fuel and air. White smoke usually results
when the fire is cooled by excessive draughts of
air, and may also be generated when the materials
being burned contain excessive amounts of moisture.
Brown or yellow smoke may result from the burning
of semi-solid tarry substances such as asphalt or
tar paper resulting from inadequate temperature and
mixing. A blue or light blue colour is often
associated with the burning of domestic refuse
consisting mostly of paper or wood products. The
blue plume contains little or no carbon or soot
particles.

Fumes

Fume particles are generally less than 1 micron in diameter and will behave like smoke. Fumes more commonly consist of metals and metallic oxides and chlorides. Also contained in fumes are common solid particulates such as fly ash, carbon, mechanically produced dust and gases such as sulphur dioxide. The fumes principally emitted, however, are actually dusts condensed from the more volatile elements in the melting of metal such as zinc, sulphur, lead, and others. The officer, therefore, will probably be more concerned with metallurgical fumes, and frequently with emissions from galvanizing operations.

Dusts

Dusts are minute particles released in the air by natural forces or by mechanical processes such as crushing, grinding, melting, drilling, demolishing, shovelling, sweeping, sanding, etc. Dust particles are larger and less concentrated than those in colloidal systems such as smoke and fumes and will settle fairly quickly on surfaces. A dust effluent, however, may also contain many submicron particles.

Dusts are produced from virtually every human activity as well as from the natural environment. Some dusty industries include mineral earth processes such as ceramic and cement manufacturing, calcining, and woodworking and feed and flour industries. Dust particles generally exceed 1 μm in diameter and are readily controlled by centrifugal separators, cloth filters and electrostatic precipitators.

Mists

Mists are liquid particulates or droplets,
about the size of raindrops, such as fog, and are
formed by condensation of a vapour, or atomization
of a liquid by mechanical spraying. Mist droplets
contain contaminant material in solution or sus-
pension. The impregnation and coating of building
materials with asphalt, or the manufacture or heating
of asphalt at batch plants may produce hazes or fogs
containing droplets of liquid asphalt. Paint spraying
operations emit liquid particulates containing
organic solvents, pigments and other materials.
Mists may also be emitted from control devices such
as cyclones and scrubbers, using a liquid air cleaning
medium. Acid particulates, such as chromic and
sulphuric acids produced from chrome plating opera-
tions, may also form mists when exhausted to the
atmosphere.

It is important to distinguish between a
cloud of liquid aerosols and a mist of liquid
droplets especially in relation to liquid contami-
nants involving sulphur compounds. For example,
sulphur trioxide exists at normal temperatures as
a liquid, but when exposed to stack temperatures
encountered in large oil-burning installations,
sulphur trioxide becomes a gas, and, after contact
with sufficient moisture in the air, forms as a
white-to-blue plume several m above the stack
(detached plume). After further contact with
moisture in the air, the sulphur trioxide is trans-
formed to a weak sulphuric acid mist. When the
moisture in the mist evaporates, a sulphuric acid
aerosol is formed, and if the concentration is

sufficient, a visible cloud. The acid mist is more
dangerous to health than the aerosol cloud, since
the latter can be inhaled and exhaled without
effect, whereas the former adheres to respiratory
tissue.

Gases

A gas is a state of aggregated matter or
a fluid of freely-moving molecules tending to expand
indefinitely and to diffuse and mix readily with
other gases. As pollutants, gases include a large
variety of inorganic and organic gases which may
have noxious, malodorous, toxic, or corrosive effects,
or which may have an effective smog-producing
potential.

Vapours

A vapour is the gaseous phase of a sub-
stance which at normal temperature and pressure is
a liquid or solid. The most important vapour in
the air pollution problem is that which results
from the evaporation of petroleum products, such
as the unburned gasoline vapours in automobile
exhaust. Gasoline vapours also originate from
processes in which volatile products are maintained
in storage tanks and from the operation of pumps,
compressors and blowers required for moving liquid
gas streams.

Another principal source of vapours
originates from the consumption, marketing and
manufacture of paints and other coating products
containing organic solvents which are used to
dilute or extend surface coatings. These are re-
leased to the atmosphere upon application.

Atmospheric Humidity and Water Vapour Plumes

A plume containing large amounts of water vapour will be visible for longer distances under conditions of high atmospheric humidity. The moisture content of the air is great enough so that water droplets in the plume are prevented from evaporating. Thus the water remains in the visible liquid phase instead of changing into the invisible vapour phase.

A "detached plume" (Figure 6-1) occurs when a moisture-laden effluent is emitted from a stack at a temperature above the boiling point of water. The plume becomes visible only after the effluent has been cooled down by the air to a temperature where the water vapour condenses to the liquid droplet state. If the atmosphere is hot, the cooling will take some time. Then, there will be a space between the top of the stack and the point where the plume becomes visible.

Water plumes can be distinguished from plumes of white particles in several ways:

1. A pure-water plume disappears rather quickly and has an appearance of wispiness as it evaporates
2. The greater frequency of occurrence and a greater length of plume in cold, wet weather than in warm, dry weather
3. The detachment of the visible plume from the top of the stack in hot, dry weather, when it takes the plume longer to cool to its saturation point

4. If there is other material
mixed with the water, the plume
of this material will remain
after the water has evaporated.

Effects on Reading of Plume Density

The stronger the wind, the more it dilutes the
plume and the less dense the effluent appears.

If the wind is blowing a plume toward an
observer, he is looking through the length of the
plume. He will be looking through a longer portion of
the plume than if he were looking through the width of
the plume. Thus, the plume will appear more dense.

An increase in the illumination of a plume
results in an increase in the contrast between the
plume and its background causing the plume to look
more dense. Cloudy skies cut down on the illumination
and thus the contrast.

An observer picks out a contrasting background
against which to view a plume. White smoke read
against a white cloud background or black smoke read
against a dark cloud background reduces the contrast
and makes the plume appear less dense.

A plume disperses more rapidly in an unstable
atmosphere than in a stable atmosphere. Downwind, a
coning plume looks less dense than a fanning plume.
However, if an observer looks at them both while they
are near the stack, their densities will be equal since
they have not begun to spread out.

When an observer looks at a plume through a
hazy atmosphere the contrast between the plume and its
background is weakened. The plume, under these
conditions, does not look as dense as it would on a
clear day.

When an observer looks at a white plume with the sun in front of him, the plume scatters more light toward the observer than is the case for an observer looking at the plume with the sun at his back. This increased scattering by the white plume itself results in a higher density reading by the observer looking toward the sun. For dark plumes on a clear day, the viewer looking toward the sun also sees a plume that appears to be more dense. On an overcast day, the two viewers agree on the density of the plume.

INDUSTRIAL ABATEMENT -   THE FEDERAL PROGRAM FOR
AIR MANAGEMENT   AIR POLLUTION CONTROL

OBJECTIVES:

The trainee will be able to:

1. List the four areas in which the
    federal government has primary
    jurisdiction;

2. Summarize the three main
    objectives of the Clean
    Air Act.

THE FEDERAL PROGRAM FOR AIR POLLUTION CONTROL

Introduction

Air Pollution control has been organized in Canada
as a joint Federal-Provincial undertaking. Because
Canada is a federal state, legislation power is divided
between the federal and the provincial governments. The
powers of the respective governments are listed in the
constitution. As pollution control was not perceived as
a major problem at the time of the original division of
powers no reference was made to it in allocating powers
between governments.

The courts have held, thus far, that jurisdiction
over pollution control is shared. The province has
jurisdiction in this area under its power to regulate
property and civil rights within the province, as well
as local works and undertakings. Provincial laws may
operate concurrently with federal laws and even when more
stringent, be seen as complimentary. The provinces have
assumed primary responsibility for air pollution control.

However, several areas exist where the federal
government has primary jurisdiction and these are:

1. works, undertakings and businesses within the
    legislative authority of the Parliament of Canada.
    This would include federal buildings, institutions
    and crown companies.

2. emissions of air contaminants in quantities or
    concentrations which have been demonstrated to
    constitute a significant danger to the health
    of persons.

3. emissions of air pollutants which would likely
    result in violation of international agreements
    or have a significant impact on bordering
    countries.

4. the composition of fuels or fuel additives.

The guiding legislation for air pollution control in
Canada is the Clean Air Act which was promulgated on
November 1st, 1971. The Act has three main objectives:

1. The chief responsibility is the promotion of a
    uniform approach to air pollution across Canada.
    Since the direct responsibility for administra-
    tion of air pollution control falls within the
    provincial jurisdiction, the existence of
    "pollution havens" resulting from differences in
    air pollution legislation from province-to-province
    becomes a possibility, and the role of the federal
    government is then to outline National Guidelines
    to provide a more uniform approach across the
    country.

2. The Act has provisions to enable the federal
    government to enter into agreements with individual
    provinces for the purpose of facilitating the
    formulation, co-ordination and implementation of
    policies and programs designed for the control
    and abatement of air pollution. This section of
    the Act is not intended to replace provincial
    jurisdiction and legislation, but is intended to
    complement and supplement provincial legislation.
    An example of federal-provincial co-operation
    might be joint research programs or the federal
    supply of monitoring equipment for provincial

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    might be joint research programs or the federal
    supply of monitoring equipment for provincial

surveys. Federal-provincial air pollution accords providing for far ranging co-operative efforts have been entered into by the federal government and several provincial governments.

3. A third objective of the Act is to provide federal government leadership in areas where federal government involvement is necessary. These areas have included:

    a. A national inventory compilation of source emission data for various pollutants.

    b. Establishment of national air quality objectives.

    c. Control of air pollution from federal government establishments and businesses under federal legislation.

    d. Control of fuel composition and fuel additives (i.e. lead additives in gasoline).

    e. Co-ordination with the provinces of a national air pollution surveillance network.

    f. Development of Federal Emission guidelines.

    g. Development of Federal Emission Regulations.

    h. Resolution of interprovincial and international pollution issues as required.

Each of these activities is referred to in subsequent sections.

National Inventories

Section 3 of the Clean Air Act refers to the Minister's mandate to collect and publish data on air pollution.

One of the first actions taken by Environment Canada was to contract with an outside consultant for the compilation of a National Emission Inventory for five major contaminants: Sulphur dioxide, particulate matter, carbon monoxide, hydrocarbons and nitrogen oxides, using 1970 as the base year. Reports have been completed for every two years since that time; compilation of the 1978 report is practically complete.

As of 1976, inventories have also been completed for arsenic, cadmium, fluoride, manganese and vanadium.

At the present time, inventories of antimony, bismuth, chromium, cobalt, barium, and tin are in final draft. Inventories of natural sources of sulphur, nitrogen and organic compounds, as well as particulate and mercury, have recently been completed. Updates of the original mercury and lead inventories are in final draft form.

These inventories are necessary for the definition of problem areas and are used for the determination of priorities for guideline and regulation development.

Air Quality Objectives

Section 4 of the Act provides for the formulation of ambient air quality objectives in terms of three ranges of quality, namely, the tolerable range; the acceptable range; and the desirable range.

The development of these objectives has been the responsibility of an expert Subcommittee of the Federal-Provincial Committee on Air Pollution.

At this time the acceptable and desirable objectives have been set for five common pollutants, i.e. sulphur dioxide, suspended particulates, ozone, carbon monoxide, and nitrogen dioxide and these are appended.

The questions of maximum tolerable range continues to be examined under the direction of the Federal-Provincial Committee.

Federal Facilities

Sections 10 to 18 of the Act refer specifically to the control of air pollutants from Federal Facilities, and describes the criteria by which sources are to be evaluated and controlled.

There are specific groups both in Ottawa and the regional offices whose primary function is ensuring that federal facilities are constructed and operated in an environmentally sound manner and there are substantial funds available for this purpose.

It is important to note that, although there is no formal requirement to comply with provincial regulations, it is the intent to have all federal facilities within Ontario in compliance with provincial, as well as federal regulations.

Fuel Composition

Sections 22 and 26 describe the federal mandate to legislate the concentration of additives in fuel produced or imported into Canada.

There are currently two such pieces of legislation being enforced by Environment Canada. These are

(i)   Lead-Free Gasoline Regulations
(ii) Leaded Gasoline Regulations

National Air Pollution Surveillance Networks (NAPS)

Section 3 of the Act defines the need for this activity. This network, which is operated in conjunction with provincial and municipal governments across Canada, continually measures and records sulphur dioxide; carbon monoxide; nitrogen dioxide; ozone; soiling index; suspended particulates and lead; dustfall; and sulphation rate, in about 40 cities.

This program provides information that can be used to determine trends and the effectiveness of control measures; in the determination of air quality objectives; and in epidemiological studies.

The data from the network monitors are published monthly and as an annual summary.

Development of Federal Emission Guidelines

The authority for this activity is Section 8 of the Clean Air Act.

For guidelines development, the requirement for air pollution control is the use of "best practicable technology" to attain containment at source. This approach guarantees that plants within an industry are treated alike and promotes a minimum, uniform requirement across the country, nullifying the existence of "pollution havens". In the choice of

best practicable technology, the status of the air pollution control technology involved for the industry and economic considerations are taken into account in adopting the various measures of control.
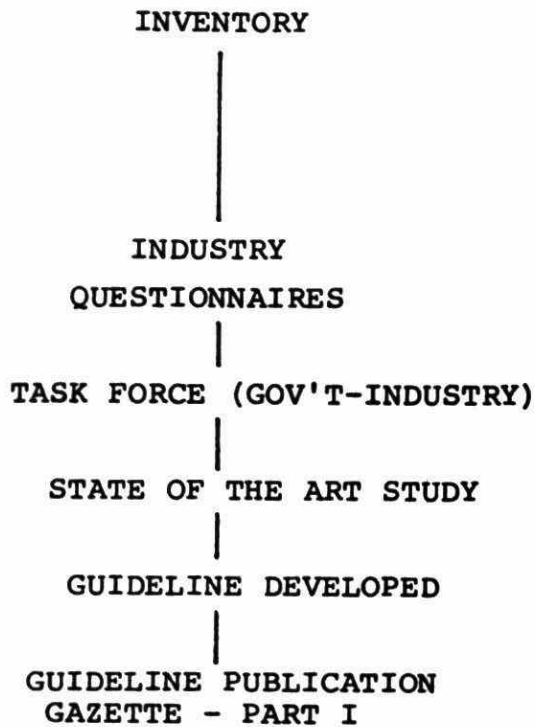
Guidelines are developed through the mechanism of federal-provincial government-industry task forces (Figure 7-1). In order to obtain information from which to derive guideline numbers, industry information as regards to processes, quantitive measures of emissions, degree of existing control measures and economic data are solicited through questionnaires. Plant visits are also made by Environment Canada personnel to update their knowledge of representative plants. Data collected from the questionnaires are used to produce a state-of-the-art study, and one of the duties of the task force is to review this document critically prior to actual guidelines development. In assessing the emissions from industry, an attempt is made to provide containment policy adapted to the particular aspects of the various industrial processes involved, i.e. best practicable technology. Prior to publication in Canada Gazette Part 1, representatives of the task force are given sufficient opportunity for discussion of proposed guidelines. As already mentioned, the guidelines are intended to provide a minimum baseline requirements for the industry across the country and local conditions may necessitate more stringent provincial regulations.
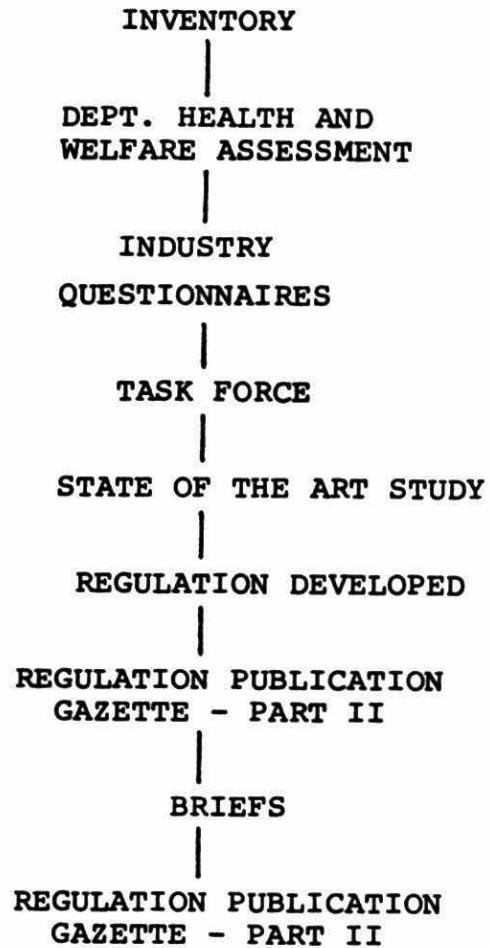
Development of Federal Emission Regulations

Under Section 7 of the Clean Air Act, any air contaminant which could constitute a significant danger to health must have its emission rate controlled by regulations. This regulation is then a legal requirement across Canada. Provincial authorities, however, retain the option of producing regulations more stringent than the federal regulations.

FIGURE 7-1

GUIDELINE DEVELOPMENT

INVENTORY

|

INDUSTRY
QUESTIONNAIRES

|

TASK FORCE (GOV'T-INDUSTRY)

|

STATE OF THE ART STUDY

|

GUIDELINE DEVELOPED

|

GUIDELINE PUBLICATION
GAZETTE - PART I

REGULATIONS DEVELOPMENT

INVENTORY

|

DEPT. HEALTH AND
WELFARE ASSESSMENT

|

INDUSTRY
QUESTIONNAIRES

|

TASK FORCE

|

STATE OF THE ART STUDY

|

REGULATION DEVELOPED

|

REGULATION PUBLICATION
GAZETTE - PART II

|

BRIEFS

|

REGULATION PUBLICATION
GAZETTE - PART II

Regulation development (Figure 7-1) follows after
an industry inventory has been conducted for various
pollutants to locate specific problem areas. In the past,
inventories have been conducted for lead, mercury, asbestos,
beryllium, arsenic, cadmium, fluorides, manganese and
vanadium. Inventories of natural sources of sulphur,
nitrogen, and organic compounds, as well as particulate
and mercury, have recently been completed. Publication
of inventories of antimony, bismuth, chromium, cobalt,
barium and tin, as well as updates of original mercury
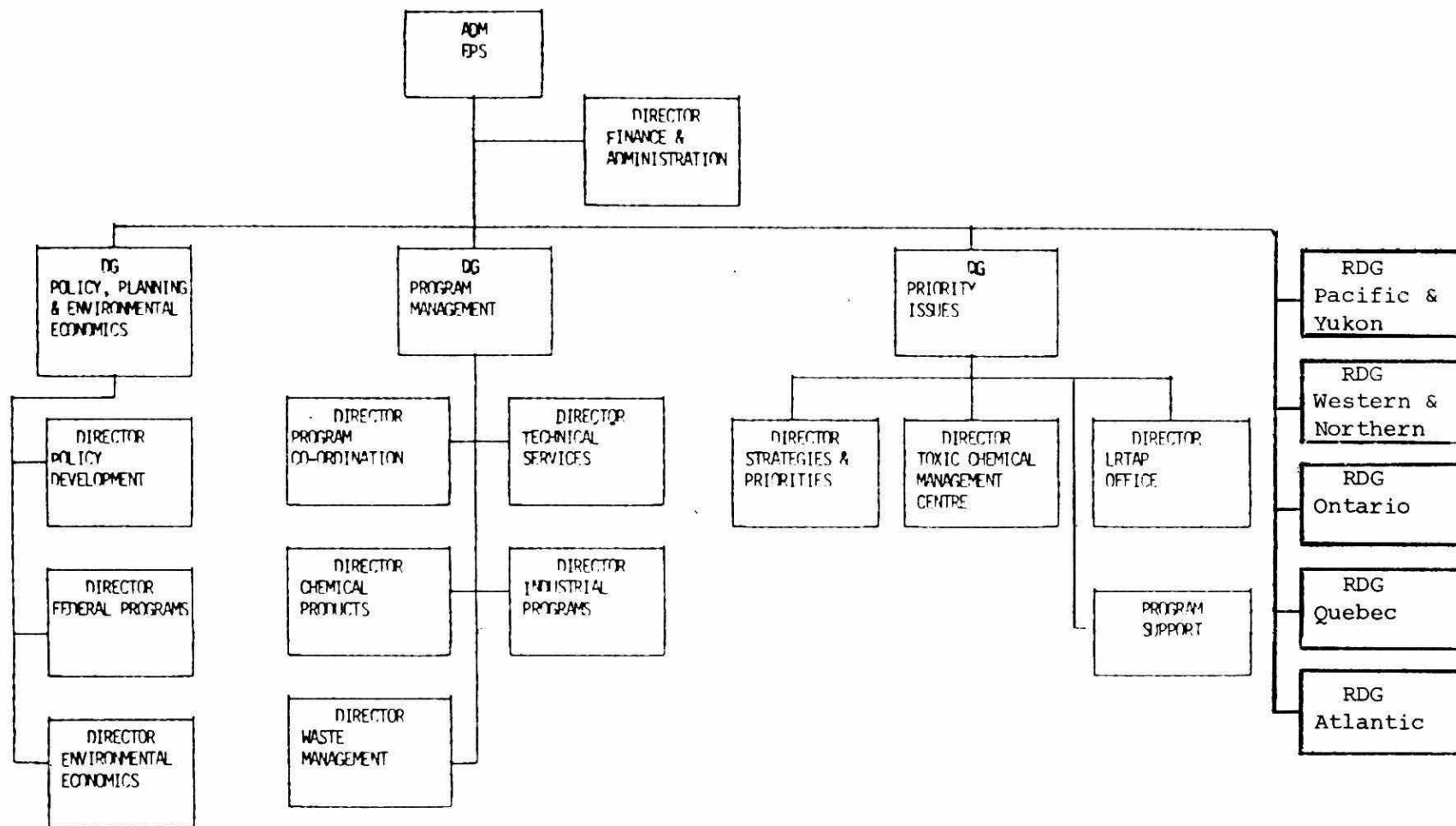and lead reports will occur shortly.

Regulation development may be carried through by
government-industry task force, such as was the case
for mercury from chlor-alkali plants, and asbestos from
the mine-mill operations; it may also be developed
internally by Environment Canada after consultation with
other government agencies and industry. An example of
this is the regulation for secondary lead smelters. In
either case, all interested parties are given an opportunity
for critical evaluation of proposed regulations by sub-
missions of briefs, after publication of the regulation
in Canada Gazette Part 1 and prior to publication in
Part 11.

Currently, lead from secondary smelters, vinyl
chloride, asbestos from mining and milling operations,
and mercury from chlor-alkali operations are regulated
under the Clean Air Act. Development work is continuing
on a regulation for arsenic emissions from gold roasting
operations. A listing of regulations, guidelines and
codes currently under development is attached.

Organization of Federal Government Air
Pollution Control Agency

The Environmental Protection Service of the Federal
Department of the Environment is currently undergoing
reorganization; the final organization structure should
be available as of January 1, 1983. An outline of the
proposed structure is given in Figure 7-2.

The Regional Office is the contact with the Province
and is reponsible for liaison with Ontario Ministry of
the Environment with regard to federal guidelines, regu-
lations and co-operative programs. In addition, it
is reponsible for the delivery of federal regulations
within the Province of Ontario. The regional office
is located in Toronto; field support personnel are also
centered in the National Capital Area District office
in Ottawa.

RDG - Regional Director General

FIGURE 7-2

Legislation	Description	Announcement in Canada Gazette
CLEAN AIR ACT (Regulations)		
Secondary Lead Smelter National Emission Standard Regulations	This regulation limits emissions of particulate matter and lead from secondary lead smelters.	July, 1976
Metallurgical Industries Arsenic Information Regulations	This regulation permits the Minister to request information related to the emission of arsenic from metallurgical work, undertakings and business	March, 1977
Metallurgical Industries Mercury Information Regulations	This regulation permits the Minister to request information related to the metallurgical work, undertakings and businesses.	March, 1977
Asbestos Mining and Milling National Emission Standard Regulations (Asbestos I)	This regulation limits emissions of asbestos at a mine or mill from crushing, drying or milling operations or from dry rock storage.	June, 1977
Arsenic Emissions from Gold Roasting Regulation	Draft regulation is now being reviewed internally. Regulation will limit emission from gold roasters.	October, 1979
Asbestos Emissions from Manufacturing Operations Regulation (Asbestos II)	Background information is being obtained and assessed.	1983
Non-Ferrous Smelters Regulation (arsenic) lead, mercury emissions)	Standard reference methods for measurement being developed. Review and assessment of control technology underway.	1983

STATUS OF ENVIRONMENT CANADA
POLLUTION REGULATIONS AND GUIDELINES

Legislation	Description	Announcement in Canada Gazette
Mercury National Emission Standard Regulation	This regulation limits emissions of mercury from mercury cell chlor-alkali plants. Industry study report available.	July 1, 1978
Vinyl Chloride National Emission Standard Regulation	This regulation limits emissions of vinyl chloride from vinyl chloride and polyvinylchloride manufacturing plants. Effective July 1, 1979. Industry study report available.	April, 1979
Lead-free Gasoline Regulation	Contract studies are underway for Socio-Economic Impact Analysis.	1982
Lead Gasoline Regulation	Stipulates permissible maximum allowable levels of lead additives in leaded gasoline.	
Fuels Information Regulation, No. 1	Collection of data from oil refineries on sulphur content of petroleum products and liquid refinery fuels.	
CLEAN AIR ACT (Guidelines)		
Cement Industry National Emission Guidelines	Indicates quantities in which particulate matter should not be emitted into the ambient air from cement producing plants.	October, 1974
Asphalt Paving Industry. National Emission Guidelines	Indicates quantities in which particulate matter should not be emitted into the ambient air from asphalt paving plants.	April, 1975

STATUS OF ENVIRONMENT CANADA
POLLUTION REGULATIONS AND GUIDELINES

Legislation	Description	Announcement in Canada Gazette
Metallurgical Coke Manufacturing Industry National Emission Guidelines	Indicates quantities in which particulate matter and sulphur dioxide should not be emitted into the ambient air from metallurgical coke manufacturing plants.	May, 1975
Arctic Mining Industry National Emission Guidelines	Indicates the quantities in which particulate matter and sulphur dioxide should not be emitted into the ambient air from arctic mining plants.	July, 1976
Ferrous Foundry Industry Guidelines	A study completing a state-of-the-art review has been printed. The study reviewed industry processes, air emissions and control technology.	1983-84
Iron & Steel Industry Guidelines	Study being finalized. Emission limit guidelines have been finalized.	1983-84
Non-Ferrous Smelters Guidelines (sulphur dioxide and particulate)	Studies underway, integrated with regulations development.	1983-84
Natural Gas Processing Guidelines	Final stages. Industry study being edited.	1982
Petroleum Refining Guidelines	Final stages. Industry study being edited.	1982
Thermal Power Generation Guidelines	Specifies emission limits for NO_2, SO_2 and particulate matter for new sources only at this time.	April 23, 1981

STATUS OF ENVIRONMENT CANADA
POLLUTION REGULATIONS AND GUIDELINES

Legislation	Description	Announcement in Canada Gazette
Wood Pulping Industry Guidelines	Guideline recommends emission limits for specific sources within a new plant. Industry study report is available.	July, 1979
In-use vehicles Guidelines	Final document under review. Background report available.	March, 1982

FEDERAL-PROVINCIAL ACCORD

An accord for the protection and enhancement of
environmental quality was signed between the Ontario
Ministry of the Environment and Environment Canada in
October 1975 and renewed in 1982. Environment Ministries
from Alberta, Saskatchewan, Manitoba, New Brunswick,
Prince Edward Island and Nova Scotia are participating
in similar agreements.

The accord calls for a broad framework which will
enable the provincial and federal governments to work
effectively together to identify potential environmental
problems, find solutions and avoid duplication of effort.

The Accords vary slightly but not substantially
among the provinces. They generally extend for five years
and provide for revision and renewal. Subsidiary agree-
ments can be signed to cover particular environmental
concerns.

Canada and the signing provinces have agreed to:

-   Determine and establish desirable levels of
    baseline environmental quality.

-   Develop national requirements and guidelines
    for pollution control by industry and
    municipalities.

-   Consult on methods of monitoring environmental
    quality and exchanging assessment data.

-   Implement pollution control programs.

-   Develop contingency plans to deal with environ-
    mental emergencies, such as oil spills.

-   Co-operate in research, exchange of technique,
    and staff training.

-       Share costs for joint programs.

The agreement provides for the free and complete
interchange of information and for the mutual adoption
of objectives such that goals adopted by one party would
become goals of the other partner.

OBJECTIVES:

The trainee will be able to:

1. Define "odour";

2. List the items an officer is con-
    cerned with in investigating an
    odour problem:

    a. Identifying and rating the in-
        tensity of the odour,

    b. Identifying the contaminant
        (odorant) causing the odour,

    c. Locating the "odour route",

    d. Locating the source of the
        odorant,

    e. Influencing some operational
        or engineering control over the
        odorant;

3. List the characteristics of odour
    perception which may be useful in
    estimating whether an odour problem
    exists;

4. List the three values used in evalu-
    ating odour:

    a. Quality

    b. Intensity

    c. Pervasiveness.

ODOURS

GENERAL

The interesting fact about odours is the enormous ability of humans to respond to thousands of distinct odour stimuli, and to detect contaminants which may originate from sources at relatively great distances. Odours can be detected in concentrations of gaseous materials as low as 1 part per billion parts of air. For this reason the nose has often been characterized as one of the best known devices for gas analysis. At the same time, the average person appears to lack the necessary vocabulary to describe odours.

A major difficulty in measuring odours is that although an odour is by legal definition an air contaminant it is essentially only an effect of an air contaminant on humans. To be more precise, it is a sense perception conveyed to the brain by nerve endings and sensory cells in the nose. Like all sense perceptions, intensity of sensation depends not only on the intensity of the stimulus but on the sensitivity of the percipient. For this reason the capacity in humans to perceive odours varies considerably, and in the same person from time to time. Some individuals are very insensitive to odours (anosmiacs) while others are acutely sensitive to odours unnoticed by most people. This fact complicates any estimate of the prevalence of an odour problem.

Odour has been defined as "the property of a substance or substances that is perceived, by inhalation in the nasal or oral cavity; that makes an impression upon the olfactory area of the body, and that, during and as a result of such inhalation, is distinct from seeing, hearing, tasting, and feeling and does not cause or result in choking, irritation, cooling, warmth, drying, wetting and other functions foreign to the olfactory area".

This definition is of practical use as it distinguishes between many sensations which may be confused with odour. The officer is concerned with:

1. Identifying and rating the intensity of an odour

2. Identifying the contaminant (odorant) causing the odour

3. Locating the "odour route"

4. Locating the source of the odorant

5. Influencing some operational or engineering control over the odorant

CHARACTERISTICS

The following characteristics of odour perception may be useful in estimating whether an odour problem exists:

1. The olfactory sense becomes fatigued after continuous perception of an odour.

2. The sensation of odour is usually detected whenever there has been a significant change in odour quality or intensity. A pleasant odour can become objectionable to one who has become used to it under continueous exposure, but increased odour intensity.

3. Odours do not, in themselves, cause physical disease, but the odour of many toxic materials may serve as a warning agent.

4. The ability to perceive odours varies from day to day with the same person.

8-2

5. Compounds of different constitution may yield similar odours, whereas compounds of very similar constitution may yield different odours.

6. An unfamiliar odour is more likely to cause complaint than a familiar one.

7. The perception level of odours decreases with increasing humidity. High humidity tends, however, to concentrate odours within certain localities.

8. Odour quality may change on dilution.

9. Some persons are capable of sensing certain odour qualities, but not others.

ODORANTS AND THEIR SOURCE

It is not necessary for abatement purposes to consider all of the odorants. Nearly all substances known, excepting those to which one is accustomed such as oxygen, have an odour. It has been said that potent odorants generally possess a significant degree of volatility and chemical reactivity such as are exhibited by the aldehydes and various classes of hydrocarbons. Also, materials of high vapour pressure tend to yield odours more readily than those of low vapour pressure.

The average person would find all familiar environmental odours objectionable were they strong enough. There is no problem about identifying these through mental association. Such familiar odours as coffee, gasoline, moth balls, roses, tobacco, wood smoke, jasmine, paint, skunk, do not need further definition to most people and can be termed characteristic odours.

However, there are many odours whose qualities
are familiar though the odorants themselves are not.
These are the so-called chemical odours, as complainants
might call them, associated with chemical and petro-
chemical processes. The odours of skunk, garlic, onions
and cabbage, for example, may arise from various sulphur
compounds, ethyl, methyl, propyl and butyl mercaptans,
respectively, generated from oil-refining processes.
These are good examples of the fact that compounds of
different constitution have similar or analagous odours.

We may further distinguish between strong,
pungent chemical odours, which offend primarily because
of intensity, and those which are obnoxious or malodorous
because of their quality. It is the latter type that
causes most complaints. These tend to be odours origi-
nating from the handling and processing of organic
compounds containing nitrogen and sulphur. The odours
arising from nitrogenous compounds may be associated
with animal odours and decomposition of animal tissue.
The odours arising from sulphur are characterized by
"rotten egg", "skunk", "decayed cabbage", as well as the
acrid, bitter sulphide odours found in metallurgical
operations. (Elementary sulphur and nitrogen do not
exhibit odours.)

The introduction of nitrogen compounds tends to
imbue substances with objectional animal odours. Amines,
in particular, can have ammoniacal, "fishy" or decayed
flesh odours. In the decomposition products of protein,
such as occur in the animal rendering industry, mostly
nitrogenous and sulphurous compounds may be involved.
These also contain hydrogen sulphide, putrescine,
cadaverine, skatole, and butyric acid. Other odorous
compounds not involving nitrogen include phenols and
cresols, employed principally in the manufacture of

resins, plastics, disinfectants, inhibitors, and
agricultural chemicals.

There is fair agreement as to which activities
produce obnoxious odours. Table 8 -1 compiled by the
Air Pollution Control Association, shows the type of
odours most frequently reported by City Bureaus. The
list here is fairly typical for most industrial econo-
mies, although the importance may change from community
to community.

RENDERING OPERATIONS

Because of its universal contribution to odour
problems, the animal rendering problem deserves special
mention.

Animal rendering consists of reducing to solids,
fats and water, animal tissues from inedible meat and
bone scrap derived either from slaughter-house remnants,
or offal from poultry, dogs, cats, or other animal
carcasses picked up from the streets. When the rendering
operation is conducted in a slaughter-house or meat
packing plant it is termed "captive" or "live" rendering.
Independent renderers, on the other hand, comprise the
animal by-product industry and may be mostly concerned
with rendering the carcasses of animals salvaged from
the streets. The products generally produced are
tallow, grease, fertilizer, and animal feed. The pro-
cessing of whole blood in a liquid form in slaughter-
houses or captive rendering operations yields solid
blood meal which is also valuable as fertilizer and in
the manufacture of glue.

Table 8-1
List of Odours Most Frequently Reported by City Bureaus

Animal Odours
1) Meat packing and rendering plants
2) Fish-oil odours from manufacturing plants
3) Poultry ranches and processing.

Odours from Combustion Processes
1) Gasoline and diesel engine exhaust
2) Coke-oven and coal-gas odours (steel mills)
3) Maladjusted heating systems.

Odours from Food Processes
1) Coffee roasting
2) Restaurant odours
3) Bakeries.

Paint and Related Industries
1) Mfg. of paint, lacquer, and varnish
2) Paint spraying
3) Commercial solvents.

General Chemical Odours
1) Hydrogen sulphide
2) Sulphur dioxide
3) Ammonia.

General Industrial Odours
1) Burning rubber from smelting & debonding
2) Odours from dry-cleaning shops
3) Fertilizer plants
4) Asphalt odours - roofing and street paving
5) Asphalt odours - manufacturing
6) Plastic Manufacturing.

Foundry Odours
1) Coke-oven odours
2) Heat treating, oil quenching, and pickling
3) Smelting.

Odours from Combustible Waste
1) Home incinerators and backyard trash fires
2) City incinerators burning garbage
3) Open-dump fires.

Refinery Odours
1) Mercaptans
2) Crude oil and gasoline odours
3) Sulphur.

Odours from Decomposition of Waste
1) Putrefaction and oxidation - organic acids
2) Organic nitrogen compounds - decomposition of protein
   Above odours are probably related to meat processing plants
3) Decomposition of lignite (plant cells).

Sewage Odours
1) City sewers carrying industrial waste
2) Sewage treatment plants.

Fish wastes in the cannery industry are
similarly rendered to yield such by-products as
fish meal, fish oil and high vitamin content residue.
The odours in the case of fish reduction in canneries
differ somewhat from the rendering plants described
above, and are readily identified by complainants.

Rendering plant odours arise from two sources:

1. General housekeeping - the decomposition of
    animal tissue and offal in transit or storage
    prior to processing.
2. Vapour emissions from improperly controlled
    rendering equipment.

Odours from the former are generally sharper
than those from vapour emissions, which are drier
and mustier in quality.

A primary source of housekeeping odours results
from the natural bacterial decomposition beginning
at the death of animal tissue, which produces power-
ful odorants whose potency increases with time and
temperature. These factors are greatly responsible
for obnoxious odours arising from offal whose ren-
dering has been delayed by transportation and handling.
The arrival and then storage of offal may be suffi-
cient to create an odour nuisance before processing.
Moreover, some organs such as the stomachs and intes-
tines are more odorous in themselves. Captive
renderers, on the other hand, are not subject to this
problem to the same extent as the independents,
since the material to be rendered is freshly acquired
from the slaughter-house.

Housekeeping odours also result from spillage, improper cleaning of plant floors, and storage in the open while awaiting rendering. The handling of materials in 200 litre drums which are not properly cleaned after use, alone can create strong odours. This also applies to captive rendering plants when processing is delayed by week-end or holiday shut downs. Monday mornings, for instance, are considered the most odorous periods in the vicinity of animal reduction plants, due to decomposed cooker feed-stock left from the previous week.

The problem of housekeeping maintenance at these plants is complicated by the fact that operators may either be anosmiacs or suffer from chronic odour fatigue. To control such odours greater cleanliness and sanitation in the plants are required.

The second source of odours arise from vapour emissions to the atmosphere from improperly controlled process equipment. Equipment involved consists mostly of boilers, driers, blood spray driers, crackling bins, rendering kettles, mixers, holding tanks, storage tanks, incinerators, and "catch basins". The most important part of the rendering operation is the cooking or dehydrating of the animal materials in steam-jacketed cooking vessels at temperatures generally exceeding 95°C. The cooker effluent contains mostly steam driven from the animal tissue - about 99% water. The material cooked generally varies between 35% to 50% moisture. The fat bone scrap is lower in moisture content than meat, and results in less vapour. The remaining 1% in the effluent consists of the odorous proteins and fats, hydrocarbons, and hydrocarbon derivatives - hydrogen sulphide, skatole,

putrescine, and cadaverine. These materials may
not only be highly odorous as discharged but may
break down on contact with air or sunlight to form
even more potent odorants.

Odours from rendering vapours may travel
considerable distances and are responsible for most
of the complaints from communities near neighbouring
rendering plants.

OTHER ODOURS

Other odours commonly experienced are hydrogen
sulphide emissions (rotten eggs), mercaptans (garlic
and skunk odours) and "sour gases" from petroleum
operations (dead cat odours); aluminum oxides from
slag or dross piles; decayed organic matter from
dumps; coffee roasting; paint, lacquer and varnish
odours.

DESCRIPTION AND MEASUREMENT

Whenever an officer investigates odour com-
plaints and attempts to establish the existence of
an air pollution source, he must identify the odour
and the odorant, describe its characteristics in
terms of delineating the objectionability of the
odour, and provide some notion as to its severity.
In making such an evaluation the following values
are used:

1.   Quality

2.   Intensity

3.   Pervasiveness

Quality

Quality describes the characteristics of odours either in terms of association with a familiar odorant, such as coffee, onions, etc., (characteristic odours), or by associating a familiar odour with an unfamiliar odorant, by analogy. Aside from such direct descriptive terms, the observer, in an attempt to be complete and accurate, may add modifiers to his description to indicate overtones to the body of an odour. These may include subjective reactions such as "fragrant", "foul", "nauseating", or characteristics of odour which may be associated with the sense of taste such as "bitter", "sweet", "sour", "burnt", or even, partially with the sense of touch as far as contaminants which are irritating are concerned, such as "pungent", "acrid", "acidic", "stinging". A contaminant may sometimes affect more than one sense; an irritant can affect the sense of smell, cause eye irritation, and be tasted.

One system of odour classification is based on six types as follows:

1. Spicy - conspicuous in cloves, cinnamon, nutmeg, etc.

2. Flowery - conspicuous in heliotrope, jasmine, etc.

3. Fruity - conspicuous in apple, orange, oil, vinegar, etc.

4. Resinous - conspicuous in coniferous oils and turpentine.

5. Foul - conspicuous in hydrogen sulphide and products of decay

6. Burnt - conspicuous in tarry and scorched substances.

Table 8-2 lists certain pollutants with suggested descriptive odours.

Intensity

Intensity is some numerical or verbal indication of the strength of an odour. Intensity may remain constant, vary or fluctuate depending on air/odorant dilution rates. A gradual increase in intensity is readily detected, although persons may have become fatigued by the odour. A sudden increase in odour intensity, however, such as might be encountered by suddenly opening a flask containing ammonia or chlorine in a room has an intensity which may be characterized by an impact. Thus, an intensity has shock value, particularly in relation to pungent or putrid odours.

Experimental findings on the discernment of odour intensity are still incomplete, but the average observer or complainant can be expected to distinguish between three intensities, weak, medium and strong, whereas the expert should be able to distinguish between the five degrees of intensity shown below and the various categories of odour quality.

Table 8 -2

Suggested Odour Descriptors

POLLUTANT OR SOURCE	DESCRIPTOR
1. Acetaldehyde	Fruity
2. Acetic Acid	Vinegar
3. Acetone	Nail Polish Remover
4. Acetylene	Garlic
5. Acrolein	Hot fats
6. African Fibre	Musty, sour
7. Allyl Mercaptan	Garlic
8. Allyl Disulphide	Garlic
9. Apiole	Parsley
10. Banana oil	Nail Polish Remover
11. Burnt protein	Burnt toast Scorched grain
12. Butyric acid	Rancid, perspiration
13. Cannery waste	Rotten eggs
14. Carbon disulphide	Rotten eggs
15. Carbon tetrachloride	Cleaning Fluid
16. Cresol	Creosote
17. Diacetyl	Sweet butter
18. Dimethylamine	Fishy
19. Dimethyl sulphide	Decayed cabbage
20. Enamel coatings	Fatty, linseed oils
21. Ethyl Mercaptan	Rotten cabbage
22. Ethyl selenide	Putrid, nauseating
23. Ethyl selenomercaptan	Foul, foetid
24. Ethyl sulphide	Foul, garlic
25. Fatty acids	Grease, lard
26. Fermentation	Yeast
27. Foam rubber curing	Sour, sulphides
28. Hydrogen selenide	Putrid
29. Hydrogen sulphide	Rotten eggs
30. Indole	Faecal
31. Iodoform	Antiseptic, iodine
32. Ionone	Violets
33. Methyl mercaptan	Decayed cabbage
34. Methylethyl ketone	Nail Polish Remover
35. Oils: castor, coconut soya, linseed	Rancid grease
36. Phenolic	Carbolic acid
37. Phenolic resins	Carbolic acid
38. Pyridine	Acrid, goaty
39. Septic sewage	Rotten eggs
40. Skatole	Faecal
41. Sludge drying	Burnt grain
42. Sulphur dioxide	Pungent
43. Trimethylamine	Fishy-ammoniacal
44. Valeric acid	Unclean body odour
45. Vanillin	Sweet, aromatic

The intensity of the odour may be noted as follows:

0 - A concentration of an odorant which produces no sensation.

1 - Concentration which is just detectable (the threshold dilution).

2 - A distinct and definite odour whose unpleasant characteristics are revealed or foreshadowed (the recognition threshold).

3 - An odour strong and objectionable enough to cause a person to attempt to avoid it, after a period of exposure.

4 - An odour so powerful as to be offensive and repulsive and bordering on being intolerable.

5 - An overpowering, nauseating, intolerable odour.

PERVASIVENESS

Pervasiveness is sometimes referred to as odour potential or threshold dilution ratios. These essentially are a measure of the ability of an odour to pervade a large volume of dilution air and continue to possess a detectable intensity.
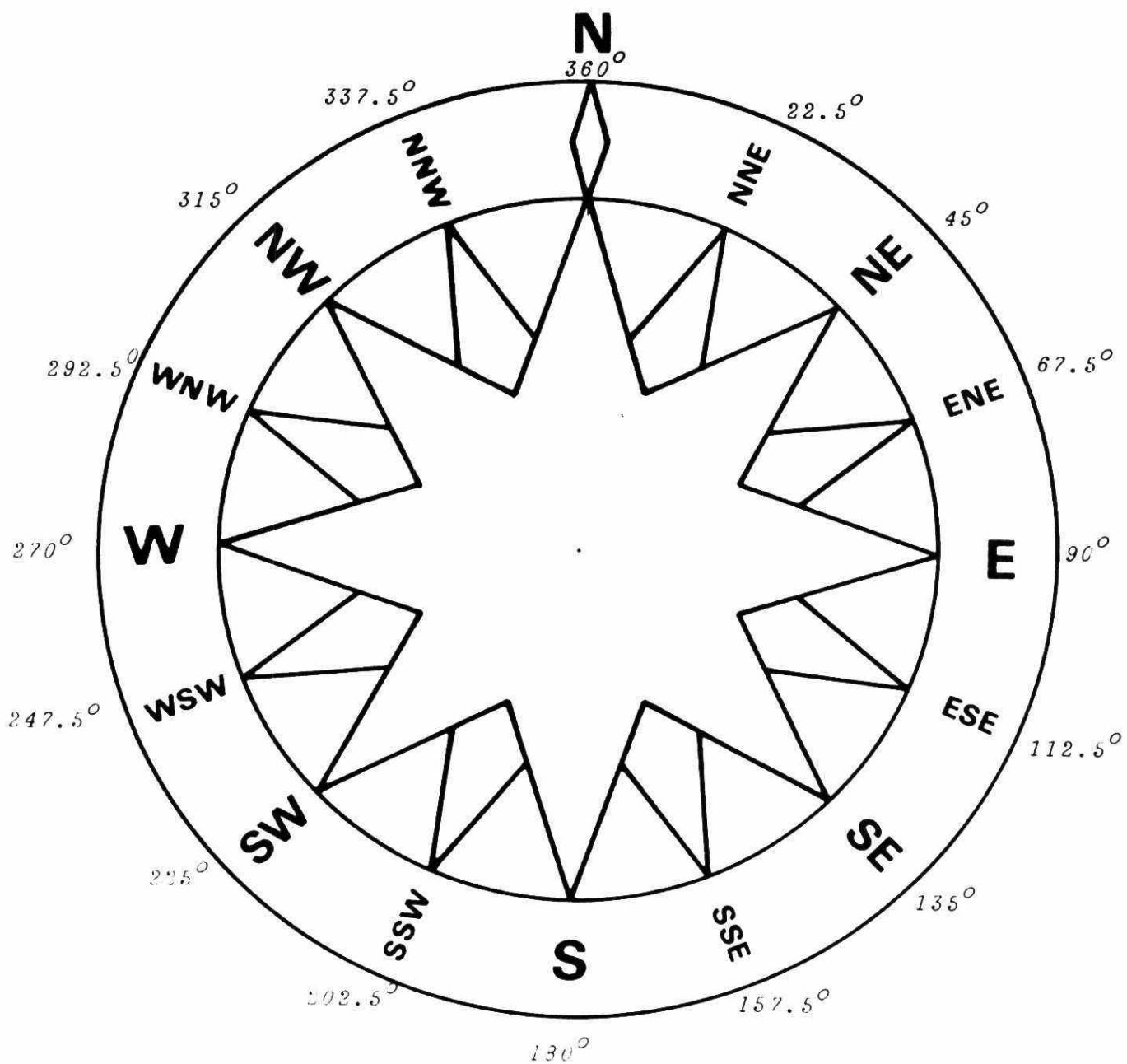
A pervasive odour such as might result from mercaptans and decomposed proteins will tend to spread in all directions over a community. An officer notes and records when tracking or establishing odour routes the general pervasiveness of odours. Such notations indicate the continuity and range of the odorant.

TRACKING ODOURS

In many odour problems tracking is unnecessary.
An experienced officer is often able to identify
the source of an odour by its quality and intensity
and may be able to relate the odour to a specific
activity. Since officers are familiar with the
industrial establishments in their particular district,
they are often able to connect the odour with a spe-
cific piece of equipment. The officer verifies his
findings by following a definite odour route in order
to prove that the odour emanates from a specific
piece of equipment. In such situations it is not
necessary to rate odours numerically but to describe
the odours as they are perceived. In these cases
the officer either follows the odour from the
suspected source as it moves downwind to affected
areas, or he proceeds from an affected area (i.e.
from the complainants themselves) upwind to the
source. The first method is for verification, the
second for tracking an unknown source.

The consensus of odour quality in the complaint
area must be identical to the odour quality emanating
from the source. With the exception of "intensity"
all significant point observations should agree.
The intensity should vary in a geographical pattern.
A point observation here is a stationary location at
which an evaluation was made of the following:

1. Odour quality and intensity

2. Wind direction (Figure 8-1 and strength
   (Table 8-3) at time of odour

3. Duration of odour

4. Time of day and date

POINTS OF THE COMPASS (16)

(FIGURE 8-1)

TABLE 8-3

The Beaufort Scale of Wind-Speed Equivalents

	General Description	Specifications	Limits of Velocity 10 m. above level ground km Per Hour
0	Calm	Smoke rises vertically.	0
1	Light Air	Direction of wind shown by smoke drift but not by wind vanes.	10
2	Light Breeze	Wind felt on face; leaves rustle; ordinary vane moved by wind.	20
3	Gentle Breeze	Leaves and small twigs in constant motion; wind extends light flag.	30
4	Moderate Breeze	Raises dust and loose paper; small branches are moved.	40
5	Fresh Breeze	Small trees in leaf begin to sway; crested wavelets form on inland waters.	50
6	Strong Breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.	60
7	Moderate Gale	Whole trees in motion; inconvenience felt in walking against the wind.	70
8	Fresh Gale	Breaks twigs off trees; generally impedes progress.	80
9	Strong Gale	Slight structural damage occurs	90
10	Whole Gale	Trees uprooted; considerable structural damage occurs.	100
11	Storm	Rarely experienced; accompanied by widespread damage.	110
12+	Hurricane	Damage	120+

Each complaint represents a point of observation. Either the officer verifies the complainant's information, or, if there are so many complaints that he cannot do so, he requests the complainant to keep a record of this information. The pattern of complaints may thus, in itself, delineate a vector which will point upwind to the source. This is especially true when complainant locations form a circle or crescent on a map, when odours are reported under relatively stable weather conditions. The projected centre of such circular point observations can be assumed to be the source area. Where an insufficient number of point observations are disclosed, the officer may make scheduled point observations in order to triangulate the source.

An estimate of wind velocity is useful in determining relative distances at which a source might be located from the complaint area. The tracking of an odour from a complaint area can be accomplished by making representative point observations along the odour route. To avoid odour fatigue officers may travel with their vehicle windows closed to maintain as relatively odour-free a vehicle as possible, then open them on arrival at a new point of observation for the purpose of comparison.

SUBJECT:

INDUSTRIAL ABATEMENT -

AIR MANAGEMENT

TOPIC: 9

PHYTOTOXICOLOGY—USE
AND SCOPE

OBJECTIVES:

The trainee will be able to:

1. List 4 of the factors why vegeta-
    tion is used for assessing air
    quality.

2. Summarize the use of Phytotoxicology
    Investigations in managing air
    quality.

3. Summarize the function of the Board
    of Negotiation for vegetation and
    livestock damage claims.

4. List at least 5 chemicals from
    the 1982 Guidelines for Soils and
    Vegetation.

PHYTOTOXICOLOGY - USE AND SCOPE

Use of Vegetation in Assessing Air Quality

Vegetation monitoring alone or in conjunction with air quality measurements has proven to be a valuable tool in assessing air quality. While air quality instruments measure concentrations of particular contaminants in the air and provide their frequency of occurrence and duration periods, they act primarily as a barometer with respect to effects. However, vegetation monitoring does provide the actual effects resulting from adverse air quality levels.

An experienced phytotoxicologist conducting a vegetation assessment survey in an area surrounding a particular source can tell whether a pollutant of phytotoxic concentration has been emitted; can diagnose what the pollutant is, for example, SO_2, HF, Cl_2, NH_3, C_2H_4; and can judge whether the pollutant came from the direction of the source. In doing this, the phytotoxicologist must be able to identify various kinds of plant species, know the symptoms of air pollution injuries, be able to differentiate injuries caused by diseases, insects and weather; and collect samples for laboratory analysis indicating whether the samples should be processed for pathology, histopathology or chemical analysis. If for chemical analysis, he must be able to indicate which contaminants the samples should be analyzed for and be able to interpret the results in context with other observations.

Observations made in the field are most important in assessing the effects of air quality. The laboratory examinations of collected samples supplement and confirm the field observations. Plant species vary considerably in their sensitivity to air pollutants, and the occurrence

of injury, the species affected, and the degree and extent of damage can only be determined from a thorough field assessment investigation.

However, there are a number of other factors which must be taken into consideration. It has been determined from both field observations and controlled environment studies that in addition to the concentration and duration of a contaminant (called dose), other factors must be acting in concert for damage to occur to vegetation. Some of these factors are the type of plant species present, the physiological and biological growth stage of the plant, and climatic variables such as air temperature, wind, relative humidity, soil moisture and light intensity. If all or most of these factors are not conductive to plant injury, plants will resist injury even at concentrations four to five times higher than those levels which are usually found to be responsible for injury. And, conversely, if these factors are especially conducive to injury, sensitive plant species can be injured by pollutant concentrations much lower than those usually required to cause injury to native vegetation. There are also differences between acute and chronic effects to consider, in which acute injury is usually caused by short-term high concentrations of a particular air pollutant, and chronic injury is caused by long-term exposure to variable concentrations of the pollutant including pollutant-free periods.

Vegetation is also used to assess the effects of photochemical oxidants. Phytotoxicology surveys conducted annually have indicated that white bean, tobacco and tomato crops in southern Ontario suffer annually as a result of photochemical air pollution. Ozone is the main phytotoxic oxidant formed in the atmosphere in the presence of sunlight and the primary pollutants, hydrocarbons and nitrogen

oxides. Oxidants are not emitted directly by any
source thus making control difficult. The main sources
of the precursor contaminants are automobiles and fossil
fuel power plants and the emissions from many miles
away in the United States can be responsible for oxidant
injury to crops in Southwestern Ontario. For example,
white bean crops in an area of about one million acres
suffer to some degree every year from the effects of
ozone. The Phytotoxicology Section is currently exami-
ning means to protect crops from ozone injury by chemical
sprays or by the use of resistant plant varities.

In addition to examining native vegetation, Phyto-
toxicology uses indicator plots to assess air quality.
These plots consisting of plant species which are raised
in a clean-air greenhouse and known to be sensitive to
different air pollutants, are established at various dis-
tances and directions from a particular source. The
indicator plants detect the presence of atmospheric pol-
lutants including ozone, sulphur dioxide, and fluorides.
A new moss bag technique is being used to assess heavy
metal and trace element contamination. The advantages
of biological monitors to assess air quality are:

1. the monitors are inexpensive,
2. numerous plots can be established surrounding
    a source,
3. the plots are easy to maintain,
4. they can readily delineate the degree
    and extent of contaminant effects surround-
    ing a source.

Use of Phytotoxicology Investigations
in Managing Air Quality

Phytotoxicology works closely with the Regions,
especially with Industrial Abatement staff. Complaints
from the public with respect to vegetation damage

9-3

and received by MOE Regional Offices are forwarded to
the Phytotoxicology Section for investigation. The
Regions are also notified by the Phytotoxicology Section
of complaints received directly from the public or by
some other route. Following the investigation the
complaints and the Region are informed whether or not
the vegetation injuries have been caused by an air pollu-
tant. If caused by an air pollutant, information on the
severity and extent of damage, and the indicated source,
is provided to the Board of Negotiation for possible
claim action and to Industrial Abatement to prevent a
recurrence of the phytotoxic emissions.

At the request of regional Industrial Abatement,
vegetation assessment surveys are conducted in the vicinity
of any potential source of a contaminant. If the results
of the survey show that pollution damage is occurring,
or contaminant levels in vegetation exceed phytotoxico-
logy guidelines, then abatement action is indicated. If
no injury to vegetation is observed, and the phytotoxico-
logy guidelines, are not exceeded then Abatement personnel
are informed that the source is not emitting excessive
quantities of the contaminant.

Assessment surveys have been conducted annually in
the vicinity of several major sources in Ontario to detect
whether effects are occurring, whether conditions have
improved as a result of abatement measures, whether condi-
tions have not improved, or whether accidents have occurred
releasing high concentrations of contaminants. In both
complaint and assessment surveys, priorities are assigned
in the handling of samples and in the preparation of
reports depending on the urgency of the situation. The
vegetation assessment reports assist the Regions in work-
ing with industries to control emissions to meet air
quality standards and criteria.

Pre-operational assessment surveys are also conducted in the vicinity of proposed major sources in order to determine background, normal conditions of vegetation growth and health. Following start-up of the industries, emissions of adverse levels of air contaminants can then be readily detected. Pre-operational studies have been conducted in the vicinity of Amherstburg, prior to start-up of an HF manufacturing plant and near Timmins prior to start-up of a zinc refinery. These studies have both shown that emission difficulties occurred after start-up which produced effects on surrounding vegetation which were not observed in the pre-operational stage.

A major pre-operational study has been in progress since 1969 in the Nanticoke area on the north shore of Lake Erie, where Ontario Hydro, Stelco and Texaco have built new large operations. To date there have been no effects detected on vegetation in the area as a result of these operations. However, an enormous amount of valuable background information has been accumulated for future use.

In past years, Industrial Abatement in the Southwestern and West-Central Regions have used phytotoxicology guidelines in Control Orders. These guidelines are used where air quality instruments have not been developed sufficiently to provide valid continuous measurements of a particular contaminant. In the case of fluorides, both vegetation injury and forage contamination levels have been stipulated in Control Orders for a fertilizer producer at Port Maitland and a hydrofluoric acid manufacturer at Amherstburg.

In addition, Conditional Approvals have been served
to companies requiring the phytotoxicology guidelines
be met. Examples of companies given Conditional Approval
are a lead recovering company in London and a poly-
ethylene manufacturer in Corunna.

Phytotoxicology soil and vegetation guidelines for
20 elements are provided in the attached Table 9-1.

Relationship of Phytotoxicology to Soil Analysis and in Animal Husbandry

Phytotoxicology surveys also study the relationship
between contaminanted vegetation, soil quality and
domestic livestock.

In the case of heavy metals, soil analyses results
in conjunction with vegetation data can help in deter-
mining whether emissions from a particular source are
occurring currently or whether they have occurred in
the past. For example, studies conducted near potential
lead sources in recent years, have differentiated the
sources according to these emissions. Of 45 potential
lead sources surveyed in Ontario in 1973, 19 did not
have excessive levels of lead in soil or in vegetation
in their immediate vicinity indicating little or no
emissions from these sources. Of the 26 sources which
did have excessive levels of lead in vegetation or in
soil it was possible to differentiate historical emitters
of lead, current emitters of lead, or both. If lead
levels were high in vegetation but not in soil this
indicated current emissions only. If lead levels were
high in soil but not in vegetation this indicated past
emissions only, whereas high levels in both vegetation
and soil indicated both past and current emissions. How-
ever, there can be exceptions, and it is important to

know the normal levels for the area, the land-use and the characteristics of the soil and vegetation sampled.

It was also possible to list the 26 sources with excessive levels of lead in their vicinity in a descending order of major to minor emitters of lead by the concentration levels encountered in soil or vegetation. Five of the 26 companies were classified as major sources of lead with concentrations of lead as high as 150,000 parts per million found in soil immediately adjacent to one of the sources.

In the case of domestic livestock, the degree of contamination of forage by lead, selenium or fluoride can assist a veterinarian in diagnosing observed clinical effects in the animals. Cattle can develop the disease "chronic fluorine toxicosis" if forage containing 40 ppm fluoride is ingested over a long period of time. Forage with over 80 ppm fluoride can be harmful if used as animal feed for only one month. Thus the Control Orders served to companies emitting fluorides have taken into consideration the forage contaminant levels. The determination of the amount of a contaminant in animal feed is also necessary in the investigation of damage claims made by farmers for livestock allegedly sickened by the consumption of contaminated forage.

Function of the Board of Negotiation for Vegetation and Livestock Damage Claims

According to Section 134 of the Environmental Protection Act, provision has been made for the mediation of livestock and vegetation damage claims by a Board of Negotiation consisting of two or more members appointed by the Lieutenant Governor in Council, should the loss

be the result of injury or damage caused by a contaminant. The Board was originally appointed in 1968 in conjunction with the promulgation of the Air Pollution Control Act, 1967.

The following procedures must be followed in order to have access to the provisions of the Act.

1. If it is suspected that a contaminant is causing or has caused injury or damage to vegetation or livestock, which may result in economic loss, the complainant must, within 14 days after the injury or damage become apparent, request an investigation. His request should be made to the Ontario Ministry of the Environment, Air Resources Branch, Phytotoxicology Section, 880 Bay Street, Toronto, Telephone 965-4516. If the request is made by telephone, it should be confirmed by a letter.

2. The Ministry of the Environment will conduct an investigation, sometimes in conjunction with specialists from other government ministries.

3. In order to have subsequent access to the Board of Negotiation the complainant must notify the owner or operator of the alleged source of the contaminant of the location of the damaged vegetation or livestock, or agree to have his name and address provided to the alleged source by the Ministry of the Environment. It is also necessary for the complainant to permit owner or operator of the alleged source of the

contaminant to enter his property to inspect
the injury or damage and to take samples
for testing and examination.

4. After the Ministry of the Environment has con-
ducted its investigation a report is sent to
the complainant and to the owner or operator
of the alleged source of the contaminant
outlining the extent of the injury or damage.

5. Assuming that the investigation defines the
cause of the injury or damage as a contaminant
and indicates the source, the two parties should
attempt to make a private settlement.

6. If a mutually acceptable settlement cannot be
arrived at, the claimant can obtain the
services of the Board of Negotiation by notify-
ing the Ministry of the Environment, Toronto,
and the owner of the alleged source of the
contaminant of the monetary amount of his claim
within a reasonable time after it can be
determined.

7. If the two parties are not able to reach a private
settlement within 30 days after notice of the
claim has been given to the Ministry of the
Environment, either party may serve notice of
negotiation upon the other party and request that
the Board of Negotiation intervene.

8. The Board of Negotiation will then meet with
both parties and in an informal manner proceed
to negotiate a settlement of the claim. This
procedure shall be without prejudice to any
subsequent proceedings.

As can be seen from the negotiation procedure, the Ministry encourages private settlement of damages by the two parties.

Two thousand complaints of suspected damage have been investigated by the Phytotoxicology Section since 1968, with approximately 50% diagnosed as being caused by contaminants and 50% as being caused by other agents such as disease, insect or adverse weather. Of the approximately 100 vegetation or livestock complaints which are confirmed annually to be contaminant-caused, about 40 complainants are satisfied in knowing that the Ministry is doing something about the problem, about 40 complainants settle their claims privately, and about 20 complainants make claims to the Ministry. This latter number is subsequently further reduced in the number of Board of Negotiation hearings requested as private settlements increase.

To bring the role of the Board of Negotiation and the activities of the Phytotoxicology Section into perspective let us briefly discuss a tree damage episode, which was investigated in the vicinity of the Gulf Oil refinery at Clarkson. Late July, the Oakville office of the Ministry and the Phytotoxicology Section received numerous calls from residents neighbouring Gulf Oil about the sudden browning of ornamental pine trees on their properties. Both Gulf Oil and the regional Industrial Abatement staff were not sure of the source, or what contaminant was responsible for the damage. The Phytotoxicology Section investigated the complaints and determined that various kinds of trees, particularly pines, had been injured in a three-mile swath leading out in a northeast direction from the Gulf Oil refinery. The field observations, based on sensitivity and resistance of various tree species and on the appearance of the symptoms of injury

indicated that hydrogen fluoride was the causal agent.
However, the company could not pinpoint any emission
source of hydrogen fluoride or find any record of an
accidental release of high concentrations of the gas.
Samples of injured and healthy foliage collected in
the vicinity of Gulf Oil were processed in the Phyto-
toxicology laboratory for chemical analysis and histo-
pathology. The laboratory results, based on fluoride
levels in the collected foliage and on cellular changes
observed microscopically in the injured leaf tissue
confirmed that hydrogen fluoride was responsible for
the injuries. The pattern of tree damage throughout the
area indicated that only Gulf Oil could be the source
of the gas. Upon receipt of the report of the investiga-
tion , Gulf Oil accepted responsibility for the emission,
having found that the incineration of polymer with free
hydrofluoric acid was suspect, and agreed to settle all
damage claims from neighbouring residents. A Control
Order has since been served to the company which requires
no further incineration of this polymer. Within the
hydrogen fluoride tree damage zone a total of 125 residents
made official claims and each property was individually
surveyed by the Phytotoxicology Section for the numbers
of trees affected and the degree of damage. If any of
the claimants is unable to reach a mutually agreeable
settlement with the company, then either party can ask the
Board of Negotiation to hold a hearing and negotiate
a settlement.

The Phytotoxicology Section also conducts a number
of research studies in the controlled environment facili-
ties (special clean-air growth chambers and greenhouses
at Brampton) to solve problems associated with complaint
and assessment surveys. In addition, the facilities are
used to determine air quality criteria and standards with

respect to vegetation effects and to assess the effects
of simulated acid rain on soils and vegetation through
the use of specially constructed precipitation event
chambers.

Table 9-1

The following guidelines have been developed by the Phytotoxicology Section for use in interpreting chemical analysis data. Excessive levels in not washed foliage and in surface soil (0-5 cm) are given for 20 elements.

Contaminant		Concentration Considered Excessive (ppm, dry weight)	
		Vegetation (not washed foliage)	Surface Soil (0-5 cm)
Aluminum	Al	400	-
Antimony	Sb	3	5
Arsenic	As	5	20
Boron	B	200	25 (1 HWS*)
Cadmium	Cd	5 (3 rural)	8 (5 rural)
Chromium	Cr	20 (10 rural)	125 (75 rural)
Cobalt	Co	10	25
Copper	Cu	30	100
Fluoride	F	35	-
Iron	Fe	800	-
Lead	Pb	100 (50 rural)	600 (150 rural)
Manganese	Mn	500	1500
Mercury	Mg	0.3 (0.1 rural)	0.6 (0.3 rural)
Molybdenum	Mo	8	5
Nickel	Ni	25 (15 rural)	100 (70 rural)
Selenium	Se	2	3
Silver	Ag	5	5
Sodium	Na	600	-
Vanadium	V	10	150
Zinc	Zn	200	600 (300 rural)

* HWS = hot water soluble

Revised 09.03.82

The above-noted levels in vegetation and soil are subject to modification based on continuing knowledge. In interpreting the significance of chemical analysis values, consideration must be given to other factors such as soil site, plant species, plant part and observed effects

SUBJECT:

INDUSTRIAL ABATEMENT -
AIR MANAGEMENT

TOPIC: 10

ATMOSPHERIC HAZARDOUS
CONTAMINANTS

OBJECTIVES:

The trainee will be able to:

1. Define what constitutes a hazardous
   contaminant.

2. List at least 5 hazardous chemicals.

3. Define: Toxicity
            Hazard
            Risk

4. List 3 methods for the identification
   of health risks.

5. Summarize Air Resources Branch
   approach to hazardous
   contaminants.

6. List the capabilities of A.R.B.
   mobile monitoring and emergency
   response.

ATMOSPHERIC HAZARDOUS CONTAMINANTS

General

An ever increasing number of chemicals are required to manufacture the goods we all use. Such chemicals are transported throughout the Province, as well as being used in specific plants, and it is very difficult to prevent some releases to the environment. As the traditional pollutants are being brought under control, the public is becoming more concerned about hazardous contaminants in the environment.

What constitutes a hazardous contaminant? An operational definition of a hazardous contaminant is:

A TOXIC SUBSTANCE which by itself, in combination with other substances, or by an environmental transformation product or metabolite:

1. Causes

   - severe, irreversible effects on human health
   - other critical biological or ecological effects

2. May cause effects through low-level, chronic exposure

and

3. Is discharged in sufficient quantity & resides in the environment in such form and for sufficient time as to create an opportunity for exposure.

Some possible long term effects of hazardous contaminants can be:

1. carcinogenicity - the ability to cause cancer

2. teratogenicity - the ability to cause deformations or birth defects

3. mutagenicity - the ability to damage genetic material, which can cause inheritable defects

Other subtle, long term toxic effects could be a reduction of learning potential in children, lowering of resistance to disease, lowering of fertility, etc.

Some chemicals which can be classed as hazardous contaminants are

Benzene
Dioxins (PCDD's)
Dibenzofurans (PCDF's)
PCB's
Polycyclic Aromatic Hydrocarbons (PAHs)
Polychlorinated Benzenes
Polychlorinated Phenols
Chlorinated Hydrocarbons
Phthalate Esters
Radon & Radon Daughters
Asbestos

Because the action of many of these chemicals is long term, there are serious difficulties in assessing the hazard   or risk from many of these compounds. Both toxicity and exposure have to be taken into account to assess the actual risk to a population.

Again, some definitions may be helpful.

1. Toxicity is the ability of a substance to
    cause damage to living tissue.

2. Hazard is the harmful effect caused by a
    toxic substance and is influenced both by
    the toxicity and the degree of exposure.
    Exposure is a function of both concentration
    of the toxic substance and the length of time
    the living organism is exposed.

    For instance, the hazard due to a toxic sub-
    stance could be dizziness and vomiting for
    exposure to a low concentration for a short
    time, while the hazard could be death for
    exposure to a high concentration for a long
    time, i.e. there may be different hazards
    from the same toxic substance depending on
    exposure.

3. Risk is the probability that the hazard will
    actually occur, usually expressed for hazard-
    ous contaminants as deaths or illness per unit
    of population. The classic example to show
    the difference between hazard and risk is that
    the hazard due to crossing the Atlantic Ocean
    by row boat or ocean liner is the same, i.e.
    death by drowning. However, the risk of incur-
    ring this hazard, i.e. the probability of
    actually drowning, is very different for these
    two modes of transport.

In order to put the comparative risks of different
activities into perspective, the following may be used
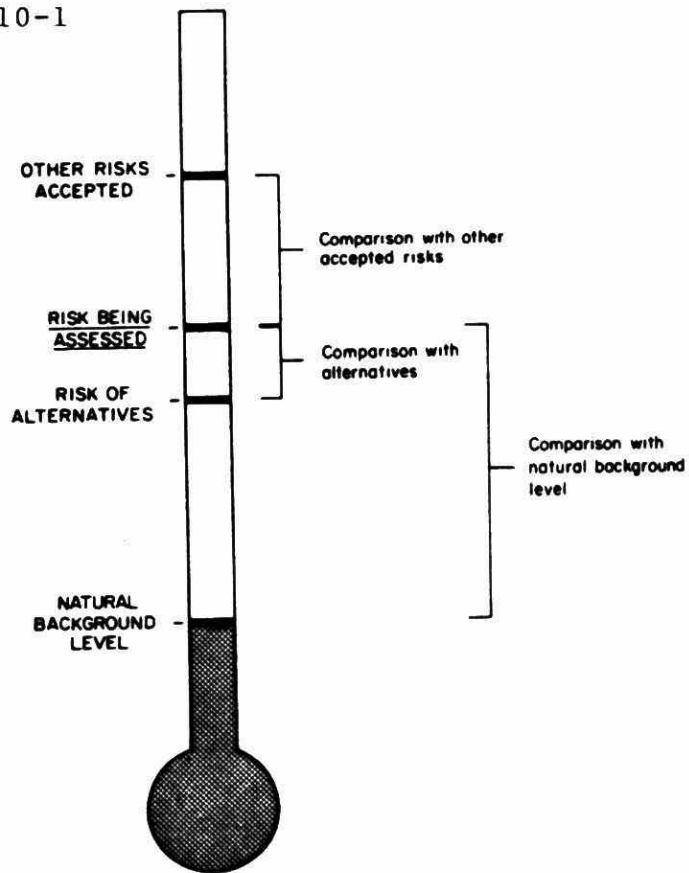as common yardsticks for measuring the acceptability
of risk.

There is about one in a million risk of death from:

$1\frac{1}{2}$ cigarettes

50 miles by car

250 miles by air

$1\frac{1}{2}$ minutes rock climbing

6 minutes by canoe

20 minutes of being aged 60

$\frac{1}{2}$ hour of President of U.S.

1 hour of being King of England

1-2 weeks of typical factory work

Regulatory agencies commonly put acceptable risk
levels for carcinogenic substances at one death per 10^5
to 10^6 people for a lifetime exposure. It is important
to emphasize that there are no riskfree options avail-
able without stopping a particular human activity associa-
ted with that carcinogenic substance altogether. It
follows than that acceptable risk is the risk associated
with the best of the available alternatives and not with
alternatives which we would like to prevail. Thus,
acceptable risk cannot be talked about in isolation from
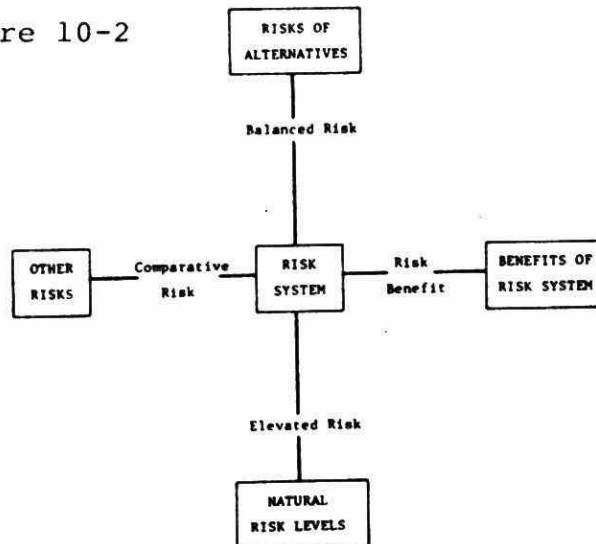costs and benefits.

Figure 10-1 shows some different ways of putting
risks in perspective. Another important factor is that
people's perception of risk can vary greatly depending
on the circumstances. For instance, voluntary risk
such as skiiing is much more acceptable than involuntary
risk such as breathing air pollution. Risks involving
large numbers of deaths, like airplane crashes, are less
acceptable than equal or greater numbers of deaths more
evenly spread through the population like car crashes.
See Table 10-1.

Figure 10-1

OTHER RISKS ACCEPTED —

Comparison with other accepted risks

RISK BEING ASSESSED —

Comparison with alternatives

RISK OF ALTERNATIVES —

Comparison with natural background level

NATURAL BACKGROUND LEVEL —

Alternative yardsticks for measuring risk
(these are not necessarily always in this order)

Figure 10-2

RISKS OF ALTERNATIVES

Balanced Risk

OTHER RISKS — Comparative Risk — RISK SYSTEM — Risk Benefit — BENEFITS OF RISK SYSTEM

Elevated Risk

NATURAL RISK LEVELS

Different ways of comparing a risk

(from Whyte & Burton, ENVIRONMENTAL RISK ASSESSMENT)

TABLE 10-1   FACTORS IN PUBLIC
RISK PERCEPTION

Factors tending to increase risk as perceived	Factors tending to reduce risks as perceived	Examples
Immediate	Latent or delayed	Tornado - drought Fire - asbestos
Direct	Indirect	Flood - drought Bridge failure - Mercury in lakes
"Dread" hazards	Common hazards	Cancer - influenza
Large number of fatalities per event	Small number of fatalities per event	Air crash - auto crash Avalanche - snowstorm
Fatalities grouped in space and time	Fatalities scattered or random in space/ time	
Mechanisms or process not understood	Mechanism or process understood	
Uncontrollable	Controllable	
Involuntary	Voluntary	Food additives - smoking Radioactive fallout - Mountain climbing
Children at risk	Children not at risk	DDT in human mother's milk
Identifiable victims	Statistical victims	In-plant workers - Cancer from environmental radiation
Lack of eduction	Education	
Lack of belief in authority of source of information	Belief in authority of source of information	Private industry - University Scientists
Much media attention	Little media attention	PCBs - LNG transport
Unfamiliar	Familiar	
Major accident	No major accident	Three mile Island Reactor - Pickering - Flixborough - Dow Plant at Sarnia Mississauga chlorine derailment - LNG transport

Identification of Health Risks

Methods for the identification of health risks include:

1. epidemiology, which is the study of populations exposed to particular hazards.

2. animal studies, in which the effects of toxic substances on animals are studied. Usually the animals are given relatively high doses of the substance, so that toxic effects can be identified clearly while using the minimum number of animals. Even so, a complete set of tests at different doses for only one animal species can cost over a million dollars.

3. Tests on tissue and individual cells to identify toxic effects.

If possible, a safe level is determined from the above data by trying to find a no effect-level and then applying a further safety factor. For carcinogens, mathematical models are used to extrapolate from high dose animal data to acceptable risk levels for humans.

Exposure to hazardous contaminants is estimated in various ways, usually by estimating or measuring the release of such substances to the environment, as well as measuring environmental levels and then predicting individual exposure.

Using the above methods, a recent estimate of the relative importance of different causes of death from cancer is shown in Table 10-2.

Air Resources Branch Role in Ministry

Approach to Hazardous Contaminants

First, the Air Resources Branch identifies atmospher-
ic hazardous contaminants and collects information on
them. This information is compiled in several ways: in
dossiers or individual contaminants, in a computerized
data base and, in short form in a Ministry Handbook.
Access to large computerized data bases is also maintained.

The information is used as resource to assist in
answering inquiries from regional personnel.   It is also
used to decide which contaminants are of most importance
and to assist in setting environmental air standards.
Liaison is maintained between this activity, the physicians
at the Ministry of Labour advising on health effects,
and the mobile monitoring units in order to decide which
contaminant should be measured in different situations.

TABLE 10-2

Tobacco, diet are highest risk
factors for cancer

| Factor | % of all cancer-deaths | |
	Best estimate	Range of acceptable estimates
Tobacco	30	25-40
Alcohol	3	2-4
Diet	35	10-70
Food additives	‹ 1	0.5-2
Reproductive and sexual behavior	7	1-13
Occupation	4	2-8
Pollution	2	0.1-5
Industrial products	‹ 1	‹ 1-2
Medicines and medical procedures	1	0.5-3
Geophysical factors	3	2-4
Infection	10	1-?
Unknown	?	?

Environmental air standards and guidelines are set
on the basis of different contaminant effects, e.g.
phytoxicity, corrosion, etc., whichever occurs at the low-
est concentration. However, health effects of hazardous
contaminants are always considered and form a major input
into the final decision on a standard or guideline. Two
such guidelines which have been set are those for asbestos
and PCB's in ambient air.

Improved measurement and monitoring methods for
hazardous contaminants are continually being developed both
within the Ministry and through the Research Grants
program which enlists the aid of university researchers.
Each year a two or three day Seminar series is held in
January to disseminate the information gained.

All of the above is co-ordinated within the Ministry
through the Hazardous Contaminants and Standards Branch.
Because hazardous contaminants often pass easily from
one environmental medium to another,

e.g. air -- water,   land -- water,

the Hazardous Contaminants and Standards Branch has a spe-
cial responsibility to deal with inter-media contaminant
problems. In 1978 Air Resources initiated an estimation
or inventory of emissions and discharges of contaminants
in Ontario for 14 chlorinated and aromatic hydrocarbons.
This is being expanded and extended by Hazardous Contaminants
and Standards Branch in association with the Canadian Chemical
Producers Associations.

Table 10-3 shows examples of programs initiated by Air
Resources to obtain information on both exposure and
effects of hazardous contaminants. The development of
better monitoring and measurement techniques is a very
important part of the effort to quantify exposure to air-
borne contaminants.

TABLE 10-3

EXPOSURE		EFFECTS
INVENTORY	MONITORING	CHARACTERISTICS/ TOXICITY/FATE
- Emission/Discharge Inventory of 14 Chlorinated Hydrocarbons and Aromatic Hydro- carbons	- Organic Vapors .... - Airborne Particulate Matter (APM)	- Chemical dossiers .... - Data access from On-Line Data basis eg. ORBIT, CIS,
- Establishing the Basis of MOE's Hazardous Contaminant Inventory System (HCIS)	- Airborne Particulate Organic Matter (APOM) .... - Atmospheric Monitoring at Chemical Spill Sites	(A.R.B. Oct./82)

Mobile Monitoring

There are four mobile air monitoring units (MAMU) with additional support vehicles. These units perform surveys at required sites in the Province, such as particular manu- facturing plants with high numbers of complaints from surrounding areas, or plants suspected of emitting specific contaminants.

MAMUs 1 and 2 can perform real time analysis for the routine pollutants sulphur dioxide, total hydrocarbons, total hydrocarbons other than methane, oxides of nitrogen (nitric oxide and nitrogen dioxide), carbon monoxide, hydrogen sulphide, mercury and ozone in the usual concen- tration ranges required by Ministry regulations.

These units can also monitor meterological conditions, such as wind direction and speed, temperature, pressure, humidity, solar radition and, by use of minisondes, the vertical temperature structure and thus stability class of the atmosphere. They can also measure the concentration of 50 to 80 different organic compounds in the atmosphere by use of cartridges filled with adsorbent materials. After air is drawn through the cartridges to collect and concentrate the vapours, the cartridge is then heated. The vapours are released into a cooled loop which further concentrates the vapour and thence into a gas chromatograph which separates the different pollutants so they can be identified and measured.

MAMU 3 contains a TAGA 3000 (Trace Atmospheric Gas Analyzer) mass spectrometer. This unit ionizes gas molecules which can rapidly transfer charge to pollutant molecules. These electrically charged pollutant molecules are then analyzed by mass spectrometer to give a very sensitive real time detection method (parts per billion to parts per trillion). Alkenes, chlorinated alkenes and benzenes, organic sulphur compounds, hydrogen fluoride, etc. can be measured.

MAMU 4 doubles as a support vehicle and emergency response vehicle. It contains photoionization detectors for hydrocarbons, a MIRAN infra red absorption detector for molecular gases, colorimetric exposure tubes for higher gas concentrations, breathing apparatus for use in emergencies as well as a repair workshop.

Emergency Response

Accidents such as train crashes involving hazardous materials can result in the release of toxic gases. The first need is for accurate information on the substances

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involved. A report was prepared under contract by Dillon Inc. to be used under these circumstances. The report identifies the toxic chemicals most likely to be involved in emergencies in Ontario and shows, in ready reference form, dangerous levels of these gases and how to measure them. Information on physical properties of these chemicals, first aid measures, safety precautions, etc. is included. The report is entitled "Atmospheric Monitoring in Transporation Emergencies".

The next requirement is to estimate how far these toxic gases could spread if released by explosion or leakage. Computer models are available to predict the dispersion of the gases and thus enable decisions to be made about the need for evacuating the population. Simple models have been programmed onto a portable computer which can be used by personnel inexperienced in computing. The portable computer can be rotated between the homes of Branch personnel so that modelling information is rapidly available at all times. Previous emergencies have happened in the middle of the night or on Sunday mornings. Professional modelling staff take over as soon as possible, using the larger Branch computer to give more sophisticated predictions.

Obviously, computer modelling can never do more than estimate the area of danger, so the mobile monitoring units go to the scene of the emergency as quickly as possible. Once there, they can measure variables such as meteorological conditions, etc., at the site. This information is fed back to the computer. More importantly the mobile units are available to measure the actual concentrations of hazardous gases downwind of the crash site. The local population can be evacuated if they are being exposed or if there is serious danger of them being exposed to hazardous levels of gases.

By combining the above approaches, the Air Resources Branch attempts to deal with the on-going challenge of hazardous contaminants, assessing present problems, defining standards and guidelines, developing new monitoring and measurement methodologies, performing surveys of air quality in the province and providing a broadly based response to major emergencies.